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16. ABSTRACT

A wide array of contaminants has been detected in the lake basin and biota of Lake Huron. Approximately 70 contaminants have been identified to be present to date. The contaminants reported most frequently and in highest concentrations are PCBs, DDT-R, dieldrin, and mercury. Several other contaminants such as toxaphene, dioxin, PBB, and dibenzofurans are emerging environmental issues but have not been sufficiently studied. In general, Lake Huron contaminant concentrations fall within the range reported for the other Great Lakes. Within the data set, Saginaw Bay generally contains the highest concentrations of organic compounds in water, sediment, and biota and appears to be the region that should receive the greatest amount of concern and future study.

Inspection of the data set on organic contaminants in Lake Huron indicates several points. Monitoring and surveillance studies should be continued for all biotic and lake basin elements. Surveillance should be conducted yearly at constant sites so that trends can be identified and comparisons can be made from site to site.

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a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Organic compounds	Monitoring		
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RUSSELL G. KREIS, JR., and CLIFFORD P. RICE

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CHAPTER ONE

INTRODUCTION

Because toxic contamination potentially threatens the health of the general public, organic pollution has emerged as a priority concern. The Laurentian Great Lakes, constituting the largest contiguous freshwater lake system on the earth's surface, has not escaped the dangers of pollution by toxic substances. Previously undetected contaminants are being found at an alarming rate because of advances in technology and methodology. However, many organic compounds have been present in the ecosystem for many years. Through the use of newly developed equipment, methods, and lower analytical detection limits, chemists are now able to identify previously undetected organic compounds. Examples of newly discovered organic substances in the Great Lakes are toxaphene, dioxin, dibenzofuran, and polybrominated biphenyl (PBB). As the decade proceeds, toxic substances will continue to be of paramount concern.

Lake Huron is the fifth largest freshwater lake in the world with a surface area of approximately 60,000 km^2, volume of 3,500 km^3, and mean depth of 53 m (Schelske 1975). It is the second largest of the Great Lakes in surface area and third largest in terms of volume (Schelske 1975). As it is situated between Ontario, Canada, and Michigan, U.S.A. (Fig. 1-1), Lake Huron serves as an international boundary and occupies a hydrologically central position in the Laurentian Great Lakes. The outflow of Lake Michigan enters Lake Huron through the Straits of Mackinac and it also receives input from Lake Superior via the St. Marys River. Typically, Lake Huron exhibits a counterclockwise circulation pattern that varies seasonally, dependent on wind stress (Sloss and Saylor 1975). However, the dominant flow is southerly toward the outlet at Port Huron,

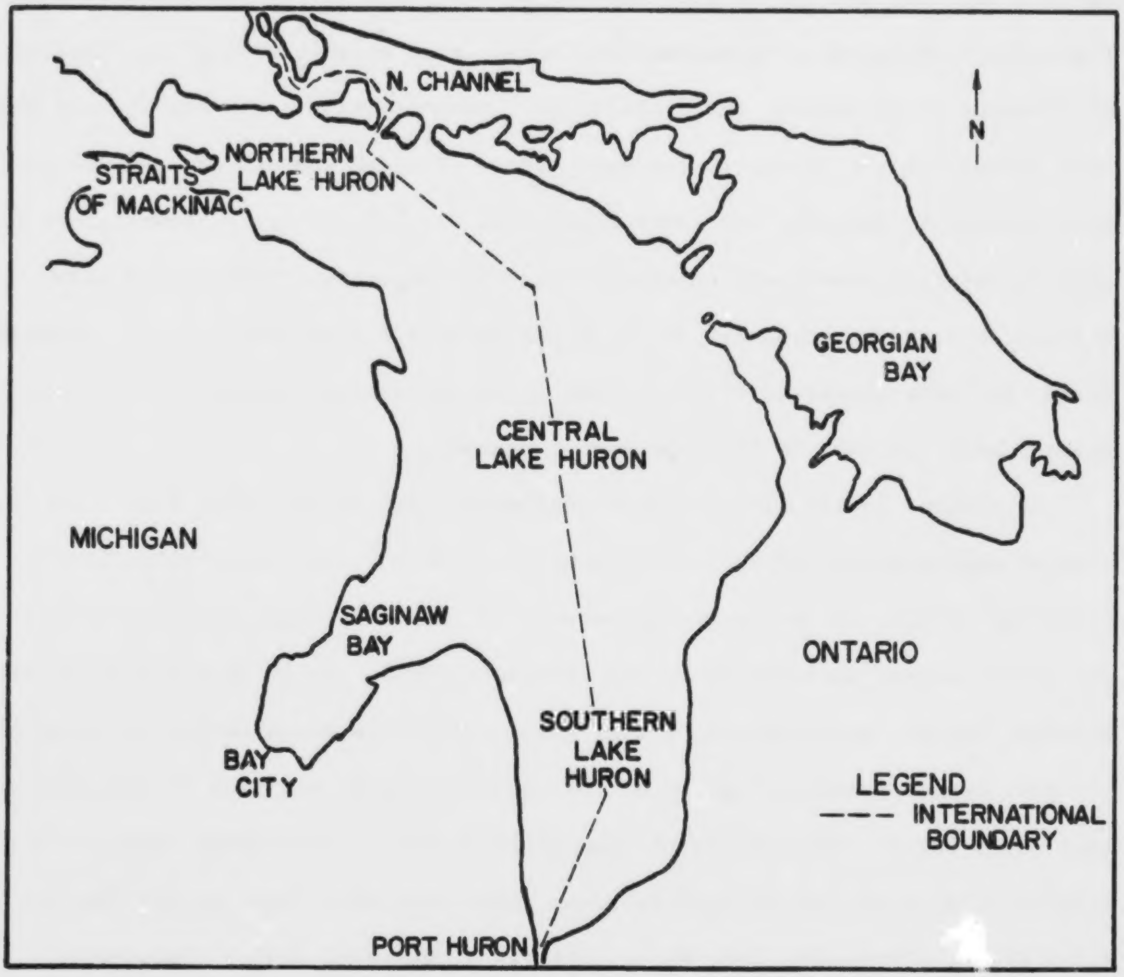
N. CHANNEL
N
NORTHERN LAKE HURON
STRAITS OF MACKINAC
GEORGIAN BAY
CENTRAL LAKE HURON
MICHIGAN
SAGINAW BAY
ONTARIO
SOUTHERN LAKE HURON
BAY CITY
LEGEND
--- INTERNATIONAL BOUNDARY
PORT HURON

Figure 1-1. Orientation map of Lake Huron.

Michigan (Saylor and Miller 1979). The Saginaw Bay water mass joins with the main southward flow as it exits the bay over the thumb area of Michigan and generally follows the U. S. coastline (Schelske et al. 1980). Lake Huron then discharges through the St. Clair River, Lake St. Clair, and the Detroit River to the lower Great Lakes.

Lake Huron can be divided into six morphometric regions (Fig. 1-1). It possesses two large embayments, Saginaw Bay and Georgian Bay, of which the latter is the largest. The North Channel lies to the west of Georgian Bay and is the northernmost border of the lake. The main lake body is comprised of the northern, central, and southern basins.

Although development has not been as extensive as in other areas of the Great Lakes, Lake Huron's importance and potential importance to the United States and Canada are easily perceived. The Lake Huron basin supports industrial and agricultural activities, which contribute to organic contamination. Generally, the distribution of organic compounds reflects sources of contamination and general usage patterns. Although organic contaminants may enter the lake in a number of ways, the primary sources appear to be tributaries, point source discharge at the shoreline, and atmospheric deposition.

A host of organic contaminants (Table 1-1) have been detected in the Lake Huron basin and its biota. The majority of these compounds are insecticides (i.e., DDT, dieldrin, lindane, chlordane, endosulfan, heptachlor, and toxaphene) which are used in agricultural areas. Toxaphene, however, used primarily in southern states and not in the Great Lakes area, appears to be an example of atmospheric contamination from outside of the basin (Rice and Evans 1984). Industrial products and bi-products (i.e., dioxin, dibenzofuran, phthalate esters, phenol, and PCBs) are produced and used locally and are present in the system.

Table 1-1. List of major organic contaminants detected in Lake Huron by common and chemical name. Bracketed numbers indicate reference source below.

Aldrin [1]	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-*endo*-*exo*-5,8-dimethanonaphthalene
Atrazine [1]	2-Chloro-4(ethylamino)-6-(isopropylamino)-1,3,5-triazine
BHC-alpha [2]	1,2,4 cis/3,5,6 trans-Hexachloro-cyclohexane
BHC-gamma (lindane) [2]	1,2,4,5 cis/3,6 trans-Hexachloro-cyclohexane
Chlordane (TECH.)	
Chlordane (cis-chlordane) [1]	1-*exo*,2-*exo*,4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
Chlordane (trans-chlordane) [1]	1-*exo*,2-*endo*, 4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
DDD-*o*,*p*' [1]	1-(o-Chlorophenyl)-1-(p-chlorophenyl)-2,2-dichloroethane
DDD-*p*,*p*' [1]	2,2-Bis(p-chlorophenyl)-1,1-dichloroethane
DDE-*o*,*p*' [1]	1-(o-Chlorophenyl)-1-(p-chlorophenyl)-2,2-dichloroethylene
DDE-*p*,*p*' [1]	2,2-Bis-(p-chlorophenyl)-1,1-dichloroethylene
DDT-*o*,*p*' [1]	1-(o-Chlorophenyl)-1-(p-chlorophenyl)-2,2,2-trichloroethane
DDT-*p*,*p*' [1]	1,1-Bis-(p-chlorophenyl)-2,2,2-trichloroethane
Dieldrin [1]	1,2,3,4,10,10-Hexachloro-*exo*-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo*-*exo*-5,8-dimethanonaphthalene
Dibenzofuran [3]	2,3,7,8-tetrachloro-dibenzofuran
Dioxin [3]	2,3,7,8-tetrachloro-dibenzo-p-dioxin
Endosulfan (I and II) [1]	6,7,8,9,10,10-Hexachloro-1,5,5a,6,9-9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide

(Continued)

Table 1-1. Concluded.

Endrin [1]	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-_endo_,_endo_-5,8-dimethanonaphth=alene
Heptachlor [1]	1,4,5,6,7,8,8-Heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene
Heptachlor epoxide [1]	1,4,5,6,7,8,8-Heptachloro-2,3-epoxy-2,3,3a,4,7,7a-tetrahydro-4,7-methanoindene
Hexachlorobenzene (HCB) [1]	Hexachlorobenzene
Methoxychlor-p,p' [1]	1,1,1-Trichloro-2,2-bis(p-methoxyphenyl)ethane
Mirex [1]	Dodecachloro octahydro-1,3,4-metheno-2H-cyclobuta [cd]pentalene
PCB [1]	Polychlorinated biphenyl
Bis(2-ethylhexyl)Phthalate (DEHP) [2]	1,2-Benzenedicarboxylic acid bis(2-ethylhexyl) ester
N-Butyl Phthalate (DBP)=dibutyl phthalate [2]	1,2-Benzenedicarboxylic acid dibutyl ester
Simazine [1]	2-Chloro-4,6-bis(ethylamino)-1,3,5-triazine
Toxaphene [2]	Polychlorinated-2,2-Dimethyl-bicyclo(2,2,1)heptane

Data from:

[1] Beroza and Caswell (1981).
[2] Eisenreich _et al_. (1980).
[3] Stalling _et al_. (1983).

The most extensive industrial development in the basin is concentrated in the Saginaw River watershed which empties into inner Saginaw Bay at Bay City, Michigan (ULRG 1977). Similarly, highest population density is centered in this region with decreasing density northward; however, isolated urban and industrial areas are scattered around the remainder of the basin (ULRG 1977). Agriculture is most extensively developed in the southern half of the basin, whereas the northern portion of the basin is largely forested and undeveloped (ULRG 1977). These factors lead to the suspicion that Saginaw Bay and the southern portion of the lake would be the most heavily impacted due to local usage and production of organic compounds.

Public alarm and scientific activity are usually heightened by the detection of anthropogenic substances in the water column and in fish tissue. However, considering the ecosystem as a whole, the entire food chain as well as each environmental compartment are of concern and may ultimately affect man, the top predator and consumer in the food web. Interactions between the lake system and its biota, particularly in lower levels of the trophic system, represent an interface between the environment and higher elements in the trophic system (Stoermer 1978). Contaminants may be sorbed merely through physical contact, i.e., onto the gills of fish (Weininger 1978); however, lower organisms in the food chain may be an introductory window to higher portions of the chain (Kalmaz and Kalmaz 1979). Even though ambient organic concentrations may be low, transfer of these organic compounds to lower elements of the trophic system appears to be efficient (Harding and Phillips 1978, Lederman and Rhee 1981). It is generally accepted that biomagnification accounts for higher organic concentrations in the top consumers of the trophic system including human beings (Goerke _et al_. 1979).

Historical studies on the various aspects of organic contamination in Lake Huron show large discrepancies in yearly sampling coverage that indicate the past and present knowledge and analytical capability possessed by scientists working on this lake. The longest historical record (1957 through 1981) of organic contamination exists for water samples. However, the largest available data set is concerned with fish during the period 1966 to 1980. Sediment data are available starting in 1969 but extend only through 1977. Studies that have been recently initiated and have limited data available are for herring gull eggs (1974 through 1980), atmospheric inputs (1975 through 1981), and algae (data only for 1974 and 1979).

In this report, data collected during the above studies are presented by year and are usually divided into subcategories, i.e., species, locality, basin. Individual mean concentrations are presented by subcategory. In most cases, yearly means are presented (and in some cases graphically illustrated) in order to illustrate long-term trends of specific compounds. Statistical analyses utilized in this report were accessed through the statistical package, MIDAS (Michigan Interactive Data Analysis System), available at The University of Michigan (Fox and Guire 1976). The MIDAS package is largely derived from Scheffe (1959), Snedecor and Cochran (1967), and Sokal and Rohlf (1969). When appropriate, log-linear regression analyses were used to determine whether organic compound concentrations were increasing or decreasing through a particular time series. Analysis of variance was utilized to determine geographic differences and differences between mean concentrations in particular year subsets. Correlation analysis examined possible relationships between independent variables.

The objectives of this undertaking are to:

1. review and compile all available organic contaminant data for each biotic and environmental compartment of Lake Huron;
2. present a chronological review of organic compounds detected in each compartment;
3. provide a data base for Lake Huron organic contamination that can be updated regularly;
4. determine long-term trends in organic contamination in Lake Huron;
5. determine which compounds should receive priority scientific research;
6. determine which compounds exceed the International Joint Commission concentration objectives for those that have been established;
7. recommend sampling and analytical procedures for best possible monitoring results;
8. identify point sources or localities which should receive priority concern and further surveillance.

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CHAPTER TWO

ORGANIC RESIDUES FROM THE ATMOSPHERE IN THE VICINITY OF LAKE HURON

The deposition of airborne organic contaminants to lake basins is a process that has only recently been identified and has received adequate attention only during the past decade in the Laurentian Great Lakes (Eisenreich *et al*. 1981). The fledgling status of airborne contaminant research is reflected in the data set available for Lake Huron, which encompasses only 1976 through 1981. In addition, the International Joint Commission has not established concentration objectives for atmospheric organic contaminants.

Atmospheric deposition of contaminants to the Great Lakes poses a serious threat to general water quality. The majority of research in this area has been concerned with the atmospheric deposition of PCBs, which is apparent in the present data set for Lake Huron. It is estimated that airborne deposition of PCBs represents a greater input to the upper Great Lakes than all other possible sources combined (Eisenreich *et al*. 1980). According to Eisenreich *et al*. (1980), the primary input is likely due to dry deposition of PCBs to the surface of the Great Lakes; however, wet deposition is also estimated to be a major contributor. Very little is known about organic contaminants other than PCBs. According to Eisenreich *et al*. (1980), estimated loadings of airborne contaminants to Lake Huron are second only to those of Lake Superior for all of the Great Lakes.

Organic Residue Levels in Atmospheric Deposition

Mean PCB concentrations detected in atmospheric deposition to Lake Huron by wet, dry, and bulk deposition are presented by date and locality (Table 2-1).

Table 2-1. Mean PCB concentrations detected in wet, dry, and bulk deposition to Lake Huron, 1976-1981.

			PCB - precipitation					PCB - dry deposition				PCB - bulk deposition				
	n	Location	Conc. ng/L	g/km^2/mo	%1242	%1254	%1260	g/km^2/mo	%1242	%1254	%1260	g/km^2/mo	%1242	%1254	%1260	Source
1976	13	M	11.0													1
1977	4	PN	63.5		37.1	59.2	3.7									2
	13	WP	50.8		44.6	48.5	6.9									2
	3	TP	22.1		43.4	51.0	5.7	0.27	27.0	64.0	8.9					2
	6	PN										2.47	25.0	67.5	7.5	2
1978		MF	21.0													3
	2	PN	53.3		26.3	69.2	4.4									2
	19	WP	24.2		29.6	59.8	10.4									2
	3	TP	14.5		31.5	60.0	8.3									2
	4	PN						0.68								2
	6	SW						0.48	21.6	60.4	17.7					2
	4	TP						0.85	43.3	47.0	9.6					2
	4	TP										0.30				2
	9	PN										1.66	25.7	68.1	6.2	2
	5	SW										0.70	29.3	59.4	11.3	2
1979	1	TP	14.7	1.4												2
	1	SW						0.50								2
	4	PN						1.35	48.9	39.4	11.7					2
	6	TP										0.85	33.4	56.4	8.2	2
	5	PN										2.52	23.7	67.8	8.4	2
	2	SW										1.00	48.4	48.3	3.3	2
1980	1	TP	21.4	0.7								0.30				2
	4	M	352.7			100.0										4
1981	3	BC										1.51	62.0	38.0		5

Source Legend:

1. Strachan and Huneault (1979).
2. Murphy et al. (1982).
3. Davis (1980).
4. Williams (1981).
5. Rice (1981).

Location Key:

MSF = Main Lake Huron at Six Fathom Bank
M = Main Lake Huron
PN = Pinconning, Mich., Saginaw Bay
WP = Whitestone Point, Mich., Saginaw Bay
TP = Tawas Point, Mich., Saginaw Bay
SW = Sebewaing, Mich., Saginaw Bay
MF = Mount Forest, Ont.
BC = Bay City, Mich., Saginaw Bay
blank = no data.

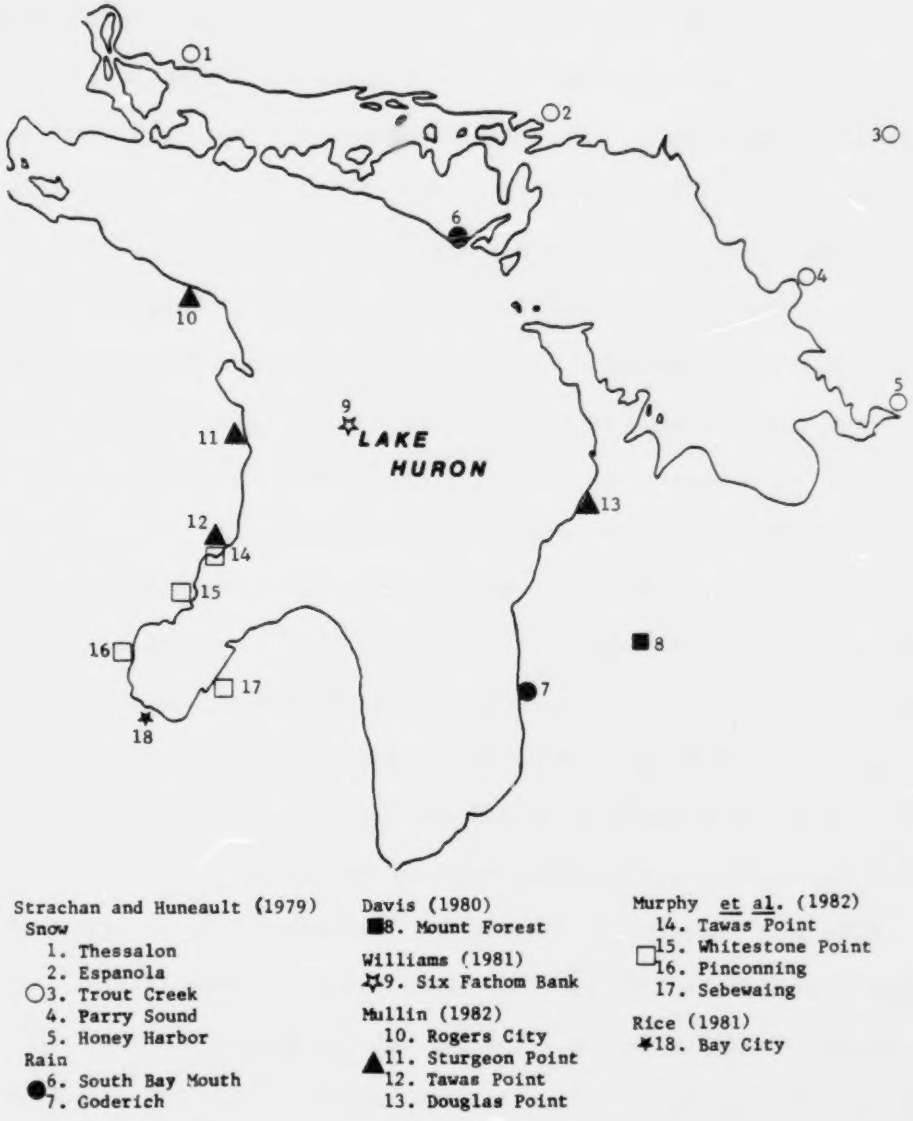
Wet deposition is defined as organic residues collected solely during a rainfall event. Dry deposition is represented by organic residues collected specifically during non-precipitation periods. Bulk deposition concentrations are either the sum of specific wet and dry deposition concentrations or represent sample concentrations collected during both precipitation and dry deposition periods. Collection sites are presented in Figure 2-1.

The highest mean PCB concentration detected in precipitation was 352.7 ng/L in 1980 (Table 2-1). These samples were collected at an offshore, stationary tower in Lake Huron anchored at Six Fathom Bank (Williams 1981). The lowest PCB concentration in precipitation was reported in 1976 at 11.0 ng/L from main Lake Huron (Table 2-1).

Comparing PCB concentrations in precipitation at other individual sites, concentrations in samples from Pinconning were higher than in those from Whitestone Point, Tawas Point, Michigan, and Mount Forest, Ontario (Table 2-1). The highest concentration reported for individual localities in Saginaw Bay was 63.5 ng/L at Pinconning in 1977 (Table 2-1). Aroclor 1254 consistently contributed the greatest proportion of PCBs to all of these areas (Table 2-1).

The highest PCB dry deposition loading was reported from Pinconning in 1979 at 1.35 $g/km^2/mo$ (Table 2-1). The lowest dry deposition loading was from Tawas Point in 1977 at 0.27 $g/km^2/mo$ (Table 2-1). Aroclor 1254 was generally the most abundant PCB component.

As may be expected, the highest PCB loading for bulk deposition was also recorded from Pinconning. Loadings of 2.52 and 2.47 $g/km^2/mo$ were reported in 1979 and 1977, respectively (Table 2-1). Again, Aroclor 1254 was the most abundant component. In the most recent sampling period (1981), a bulk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LAKE HURON
Strachan and Huneault (1979)
Snow
○ 1. Thessalon
2. Espanola
3. Trout Creek
4. Parry Sound
5. Honey Harbor
Rain
● 6. South Bay Mouth
7. Goderich
Davis (1980)
■ 8. Mount Forest
Williams (1981)
☆ 9. Six Fathom Bank
Mullin (1982)
▲ 10. Rogers City
11. Sturgeon Point
12. Tawas Point
13. Douglas Point
Murphy et al. (1982)
☐ 14. Tawas Point
15. Whitestone Point
16. Pinconning
17. Sebewaing
Rice (1981)
★ 18. Bay City

Figure 2-1. Atmospheric deposition collection sites.

deposition loading of 1.51 g/km^2/mo was reported from Bay City (Table 2-1). In this report, Aroclor 1242 was more abundant than Aroclor 1254.

All other compounds detected in precipitation were recorded in 1976 (Strachan and Huneault 1979), except PCT (polychlorinated terphenyls) which was detected in 1980 (Williams 1981). PCT was reported at a mean concentration of 240.9 ng/L. It was sought in four samples and exhibited a range from not detected to 960.0 ng/L. Concentrations reported are: two samples - not detected, 3.60 and 960.0 ng/L (Williams 1981).

Of the other organic contaminants detected in precipitation in Lake Huron by Strachan and Huneault (1979), alpha BHC showed the highest concentration of 13.3 ng/L. Methoxychlor was recorded at 9.5 ng/L and lindane at 6.0 ng/L. DDT-R and dieldrin were detected at 2.7 and 1.0 ng/L, respectively. Endosulfan II showed a higher concentration at 2.1 ng/L than did endosulfan I at 0.1 ng/L. HCB was not detected in precipitation.

Organic residue data have been obtained from Georgian Bay and North Channel snow (Strachan and Huneault 1979). Of the nine compounds sought in snow, PCBs were the most abundant at a concentration of 18.0 ng/L (Table 2-2). Alpha-BHC was detected at 0.8 ng/L and DDT-R was found at 0.4 ng/L (Table 2-2). Methoxychlor and HCB were observed at 0.2 and 0.1 ng/L, respectively. Lindane, endosulfan (I and II), and dieldrin were not detected.

PCBs were detected in Saginaw Bay ice (Table 2-3) during three winter sampling periods in 1978 and 1979 (Murphy and Schinsky 1983). Sample localities are presented in Figure 2-2. The highest PCB weight was observed in February 1978 at 318.0 ng (Table 2-3). A lower weight of 110.0 ng was observed in January 1978 (Table 2-3). In February 1979 a weight of 306.0 ng was recorded. Even though the lowest PCB weight was observed in January 1978, the greatest

Table 2-2. Organic residues detected in Georgian Bay and North Channel snow, 1976-1977. n = 5.

Compound	Mean Concentration (ng/L)
Total PCB	18.0
lindane	ND
alpha BHC	0.8
DDT-residues	0.4
endosulfan I	ND
endosulfan II	ND
dieldrin	ND
methoxychlor	0.2
HCB	0.1

ND = not detected
Data from Strachan and Huneault (1979).

Table 2-3. PCB accumulation on the frozen surface of Saginaw Bay, 1978-1979.

	Collection Times		
	January 1978	February 1978	February 1979
Number of sites	3	4	5
Number of cores	16	18	29
Total PCB (ng)	110.0	318.0	306.0
Total area of cores (m^2)	.073	.091	.132
Days of ice cover before sampling	19	61	43
Deposition rate to ice ($gm/km^2/mo$)	2.3±0.7	1.8±0.4	1.7±1.3

Data from Murphy and Schinsky (1983).

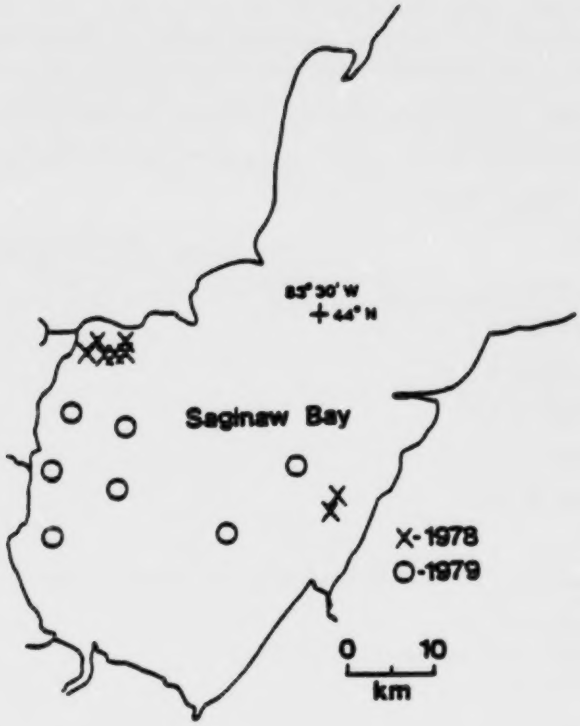

Figure 2-2. Locations of Saginaw Bay ice samples, 1978 and 1979 (from Murphy and Schinsky 1983).

deposition rate of 2.3 gm/km^2/mo was calculated due to fewer days of ice cover and a smaller core area (Table 2-3). Deposition rates of 1.8 and 1.7 gm/km^2/mo were calculated for February 1978 and 1979, respectively. Using these loadings, Murphy and Schinsky (1983) calculated that 8.0 kg and 6.5 kg of PCB were deposited upon the ice of inner Saginaw Bay in 1978 and 1979, respectively.

Annual PCB loadings to Lake Huron from precipitation, dry deposition, and bulk deposition are presented for specific localities and for Lake Huron proper on an area basis (Table 2-4). Pinconning showed the highest PCB loading in precipitation for the individual sites at 39.0 g/km^2/yr (Table 2-4). PCB loadings for Lake Huron are reported at 14.0 and 2.48 g/km^2/yr (Table 2-4).

Table 2-4. PCB loadings to Lake Huron.

LOCATION	DEPOSITION RATE	SOURCE
Precipitation	g/km^2/yr	
Whitestone Point	11.0	Murphy et al. (1982)
Pinconning	39.0	Murphy et al. (1982)
Tawas Point	14.0	Murphy et al. (1982)
Lake Huron	14.0	Murphy et al. (1982)
Lake Huron	2.48±1.78	Mullin (1982)
Dry Deposition		
Pinconning	27.0	Murphy et al. (1982)
Sebewaing	24.0	Murphy et al. (1982)
Tawas Point	16.0	Murphy et al. (1982)
Lake Huron	25.0	Murphy et al. (1982)
Bulk Deposition		
Pinconning	20.0	Murphy et al. (1982)
Sebewaing	7.0	Murphy et al. (1982)
Tawas Point	10.0	Murphy et al. (1982)
Total PCB Wet Deposition	kg/yr	
Lake Huron	825.0#	Murphy et al. (1982)
Lake Huron (less Saginaw Bay, Georgian Bay, and North Channel)	124.1±88.82	Mullin (1982)
Lake Huron	1,500.0*	Eisenreich et al. (1980)
Total PCB Dry Deposition		
Lake Huron	1,500.0#	Murphy et al. (1982)
Lake Huron	5,700.0*#	Eisenreich et al. (1980)
Total Bulk Deposition		
Lake Huron	2,325.0	Murphy et al. (1982)
Lake Huron	7,200.0*	Eisenreich et al. (1980)

Standard deviations and (ranges) are presented for some loading estimates.

#Value calculated from the proportion of bulk deposition to either wet or dry deposition.

*Estimated value which is calibrated from best fit data for the Great Lakes basin.

Pinconning also showed a slightly higher annual PCB dry deposition loading than the other two sites at 27.0 $g/km^2/yr$ (Table 2-4). A loading of 25.0 $g/km^2/yr$ is calculated for dry PCB deposition for Lake Huron (Table 2-4).

Annual bulk PCB deposition was highest at Pinconning for the three sites examined at 20.0 $g/km^2/yr$ and was primarily affected by large precipitation loadings (Table 2-4).

The annual contribution of PCBs to Lake Huron by wet deposition on a weight basis was 825.0 kg/yr which was calculated from the proportion of wet loadings to the total bulk loading. Some other loadings discussed below were similarly calculated (Table 2-4). Total wet PCB deposition to main Lake Huron (exclusive of Saginaw and Georgian Bays and the North Channel) was calculated at 124.1 kg/yr. An estimated loading of 1,500.0 kg/yr (Table 2-4) was proposed by Eisenreich _et al_. (1980). Total dry PCB deposition is calculated at 1,500.0 kg/yr and estimated by Eisenreich _et al_. (1980) at 5,700.0 kg/yr (Table 2-4). Total bulk PCB deposition for Lake Huron is 2,325.0 kg/yr (Table 2-4). A larger estimate of 7,200.0 kg/yr (Table 2-4) was also proposed by Eisenreich _et al_. (1980). Estimated wet and bulk loadings of numerous organic compounds are presented in Table 2-5 (Eisenreich _et al_. 1980).

Summary

Most atmospheric data for Lake Huron are concerned with wet, dry, and bulk deposition of PCBs. Data on other organic residues are very sparse. No data for organic concentrations specifically in the air over Lake Huron are available. Most depositional data were collected from areas adjacent to Saginaw Bay. Because the data set on organic residues spans only the time period 1976 to 1981, very little can be concluded about trends. However, some general points can be drawn because many sites were sampled on a yearly basis.

Table 2-5. Deposition of airborne trace organics to Lake Huron.

Compound	Wet Deposition Loading (10^3 kg/yr)	Estimated bulk deposition Loading (10^3 kg/yr)
Total PCB	1.5	7.2
Total DDT	0.25	0.43
-BHC	0.77	2.4
-BHC	0.25	11.6
Dieldrin	0.10	0.55
HCB	0.10	1.2
p,p'-Methoxychlor	0.40	6.1
Endosulfan I	0.10	5.8
Endosulfan II	0.15	5.8
Total PAH	5.0	118.0
Anthracene	0.10	3.5
Phenanthrene	0.10	3.5
Pyrene	0.10	6.1
Benz(a)Anthracene	0.15	3.0
Perylene	0.05	3.4
Benzo(a)Pyrene	0.10	5.8
DBP	0.30	12.0
DEHP	0.30	12.0

Data from Eisenreich *et al*. (1980).
Data are estimated loadings calibrated from best fit data for the Great Lakes basin.

In regard to wet, dry, and bulk deposition of PCBs, the highest concentrations reported were generally for the most recent period in which the particular parameter was sampled. Wet and dry PCB deposition were highest during 1980 and 1979, respectively, the last sampling period for those parameters. For bulk PCB deposition, a lower loading was recorded for 1981 than 1979. However, the loading in 1980 was reported for the site at Tawas Point, which generally had low concentrations, while Pinconning, which typically had high concentrations, was not sampled. In all cases, Aroclor 1254 was the most abundant PCB component.

One conclusion that can be drawn from this data set on PCBs is that deposition for wet, dry, and subsequently bulk PCBs was highest at Pinconning for the sites in Saginaw Bay.

Because Tawas Point was sampled on a yearly basis from 1977 to 1980, it may be informative to look at the trend at this site which seems to resemble the general trend for all localities. The highest PCB concentration in precipitation was observed in 1977. A substantially lower concentration was recorded in 1978, then a slightly higher concentration was observed in 1979. A higher concentration was recorded in 1980; however, it was still slightly less than the concentration reported in 1977. The pattern roughly resembles a hyperbolic curve.

For the other contaminants detected in precipitation in 1976 samples, alpha BHC, methoxychlor, and lindane were in highest concentrations, respectively. However, in 1980 a very high concentration of polychlorinated terphenyls was reported in precipitation.

Concentrations of PCB detected in snow samples were roughly equal to concentrations found in rainfall. Similarly, PCB loadings to Saginaw Bay ice were within the range reported for bulk PCB loadings, for the same general vicinity. Eisenreich _et_ _al_. (1980) proposed, from estimated loadings, that dry PCB deposition likely contributes a much larger proportion of PCB bulk deposition than does wet deposition. From the measured concentrations reported in this review, it appears that dry deposition contributes roughly twice as much PCB to Lake Huron than does wet deposition.

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CHAPTER THREE

ORGANIC CONTAMINANTS IN THE WATERS OF LAKE HURON

Investigations into organic contaminants in water samples from Lake Huron date back to 1957 (MDNR 1957-1978). The Federal Water Pollution Control Administration (Public Health Service) also initiated a program to determine the status of major U.S. waterways concerning organic pollution in 1958 (Weaver *et al*. 1965), however, sampling did not include Lake Huron until 1960 (Briedenbach *et al*. 1967). These records and other early data for DDT-R, dieldrin, aldrin, endrin, and a number of other compounds (MDNR 1957-1978, Lichtenberg *et al*. 1970, ULRG 1977) are reported as not detected in Lake Huron water samples. Although they do not supply numerical data in discerning long-term concentration trends, they do provide useful background data in assessing early conditions in Lake Huron.

The Upper Lakes Reference Group report to the International Joint Commission (1977) and Konasewich *et al*. (1978) summarized organic contaminants detected in the waters of Lake Huron and their tributaries through 1975 and 1976, respectively. To supplement these data, additional pre-1976 contaminant data and recent analytical results through 1981 are presented (Table 3-1). Several investigations by Frank (1977, 1981), and Frank *et al*. (1981) on the contaminant content of riverine suspended solids have not been included. Although their values are very useful for loading estimates, due to the lack of constant volumes analyzed they are not convertible to whole water concentrations which would be necessary to make them compatible with the remainder of the data set. Furthermore, they are rivermouth collections and are of less importance in estimating conditions in open Lake Huron. Data from Lake Huron watersheds or

Table 3-1. Mean concentrations (ng/L) and % residues of major contaminants detected in Lake Huron water samples, 1957-1981.

				P C B					D D T																		
Year	Location	n	Nearshore, Off-shore, River	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDD	% p,p'DDE	% p,p'DDT	% o,p'DDT	Dieldrin	Aldrin	Endrin	Heptachlor	Heptachlor Epoxide	Chlordane	Lindane	Alpha BHC	"Apparent" Toxaphene	Cyanide (mg/L)	Phenols (mg/L)	DEHP	DBP	Source
1957		7																						0			1
1960	STC	1	R						ND					T		ND											2
1961	STC	1	R						T					T		ND											2
1962	STC	1	R						T					T		ND											2
1963	STC	1	R						ND					ND		ND											2
1964	STC	2	R						ND	ND	ND	ND		ND	ND	ND	ND	ND									3
1965	STC	1	R						ND	ND	ND	ND		ND	ND	ND	ND	ND			ND						2
1965		176																						2.03			1
1965		37																					0.02				1
1967	SB	1	R						ND	ND	ND	ND		T	ND	ND			ND	ND	7.0	ND					4
1967	STM	1	R						ND	ND	ND	ND		4.0	ND	ND			ND	3.0	ND	ND					4
1967	STC	1	R						ND	ND	ND	ND		ND	ND	ND			ND	ND	ND	ND					4
1967			N																					0			5
1968		12																						1.5			1
1968	SB	1	R						ND	ND	ND	ND		ND	ND	ND			ND	ND	ND	ND					4
1968	STM	1	R						ND	ND	ND	ND		ND	ND	ND			ND	ND	ND	ND					4
1968	STC	1	R						ND	ND	ND	ND		ND	ND	ND			ND	ND	ND	ND					4
1973		4	O																							2,450	6
1974	GB	13	N																					0.52			7
1974	STM	403	R																					10.92			8
1974	SB		N	0-23	44.0	13.0		44.0	<3.0	33.3	33.3	33.3		0.6											1,300		9
1974	SPR		R																					3.0			10
1974		15	O	ND						ND	T	ND	ND	T	ND	ND	T	ND	ND	T							11
1974		5		ND	ND	ND		ND	1.0-4.0	ND	ND			T													12
1974																								1.0			7
1975		16		7.0		57.0		43.0	4.0	25.0	25.0	25.0	25.0	0.6					1.0	0.5							1
1975	SPR		R																					1.3			10
1975-76		14	R	0.2					0.2					0.1		ND		ND	0.1	ND							13
1976		6	N																						1,600		14
1976	SB	8	N																						2,250		14
1976	SB		R																						1,000	1,000	15
1976-77	SG	20	R	0.3					0.4					0.08		ND		0.05	0.2	ND	0.3						13
1977	SB		N	25.0																							16
1979	SB	118	N	24.4	51.1			48.7																			17
1979	HB	11	N	191.0		31.8		68.2																			18
1980		8	O	0.260					0.026		38.5	61.5															19
1980	NC	3	O	1.56					0.091		61.5	38.5															19
1980	GB	4	O	1.171					0.055		63.6	36.4															19
1980			O																			0.1-1.0					20
1980-81			O																			1.6					21
1981		3	O	0.398					0.023		47.8	52.2															19
1981	NC	1	O	0.110					0.022		31.8	68.2															19
1981	GB	1	O	0.110					0.007		42.8	57.2															19

LEGEND FOR TABLE 3-1

Source Legend:

1. Michigan Department of Natural Resources (1957-1978). Storet.
2. Breidenbach et al. (1967).
   Detection limits - DDT 2.0 ng/L; all others 1.0 ng/L.
3. Weaver et al. (1965).
   Detection limits - DDD and heptachlor epoxide 75.0 ng/L; BHC 25.0 ng/L; all others 2.0 ng/L.
4. Lichtenberg et al. (1970).
   Detection limits - chlordane 5.0 ng/L; toxaphene 1,000.0 ng/L; all others 2.0 ng/L.
5. Upper Lakes Reference Group (1977).
6. Strachan (1976).
7. Ross and Chatterjee (1977).
8. Kinkead et al. (1976).
9. Michigan Water Resources Commission (1974).
10. Ross et al. (1977).
11. Glooschenko et al. (1976).
    Detection limits - endrin, chlordane, endosulfan, methoxyclor 0.01 ng/L; PCB 0.1 ng/L; all others 0.005 ng/L.
12. Michigan Department of Natural Resources (1974).
    Detection limits - p,p'DDD, p,p'DDE, DDT-R, dieldrin 1.0 ng/L; PCB 10.0 ng/L.
13. Ontario Ministry of the Environment (1978).
14. Michigan Department of Natural Resources (1978).
    Detection limits - DBP, DEHP 1,000.0 ng/L.
15. Ewing et al. (1977).
16. Richardson et al. (1980).
17. Richardson et al. in prep.
18. Anderson et al. (1982).
19. Filkins and Smith (1982).
20. International Joint Commission (1981).
21. Swain (1982).

Location Key:

SB = Saginaw Bay
STM = St. Marys River
STC = St. Clair River
SPR = Spanish River
SG = Sagueen River
NC = North Channel
GB = Georgian Bay
HB = Harbor Beach, Michigan
T = trace
ND = not detected
blank = no data

specific rivers are also not included unless the samples were obtained directly from the rivermouth area. These and other locations are noted (Table 3-1). St. Marys River data are included as Lake Huron values because it is geographically part of the Lake Huron Basin; however, they may more directly reflect the condition of the Lake Superior water mass. Conversely, St. Clair River values are presented as being indicative of the Lake Huron water mass.

Organic Contaminant Levels in Lake Huron Water

PCBs

The highest mean PCB concentration of 191.0 ng/L was observed in 1979 at Harbor Beach, Michigan (Anderson et al. 1982). The next highest water concentrations are reported for Saginaw Bay. Mean PCB concentrations in Saginaw Bay between 1974 and 1979 seem to be internally consistent with the highest mean concentrations at 25.0 ng/L. Similarly, reported open lake concentrations are consistent (0.1-1.56 ng/L) with the highest observed offshore concentrations noted in the North Channel (1.56 ng/L) and Georgian Bay (1.17 ng/L) in 1980 (Filkins and Smith 1982 - see Appendix). However, these high concentrations may be due to shoreline proximity and are therefore influenced by resuspension events in these areas (J. C. Filkins, personal communication). Concentrations for Saginaw Bay, Thunder Bay, and Harbor Beach exceed the IJC objective level of 1.0 ng/L. Mean concentrations for Georgian Bay and the North Channel in 1980 also exceed the IJC concentration objective. However, all 1981 concentrations were below the IJC concentration objective of 1.0 ng/L.

DDT

Traces of DDT residues (o- or p,p'-DDT + o- or p,p'-DDD + o- or p,p'-DDE = DDT-R) were first reported in the St. Clair River in 1961 and 1962 (Breidenbach et al. 1967). DDT-R was subsequently detected in Saginaw Bay at 3.0 ng/L in 1974 (Michigan Water Resources Commission 1974). Highest concentrations were observed in Thunder Bay (4.0 ng/L) in 1975 and in northern Lake Huron (1.0 to 4.0 ng/L) in 1974 (MDNR 1957-1978, 1974). Substantially lower concentrations (0.2, 0.4 ng/L) were reported for the mouth of the Saugeen River (Ont. Ministry of the Environ. 1978) and in open Lake Huron (0.026, 0.023 ng/L) (Filkins and Smith 1982). Concentrations for 1974 and 1975 in Thunder Bay and Saginaw Bay exceed the IJC objective of 3.0 ng/L; however, all subsequent reported concentrations were substantially below the objective level.

Dieldrin

Dieldrin was detected in trace amounts in the St. Clair River from 1960 to 1962 (Breidenbach et al. 1967). The single highest concentration (4.0 ng/L) was reported in 1967 for the St. Marys River (Lichtenberg et al. 1970). Substantially lower concentrations were observed since then (trace to 0.1 ng/L). Aldrin has not been detected in Lake Huron samples; therefore, all concentrations, except the 1967 concentrations, are below the IJC objective concentration of 1.0 ng/L for the dieldrin-aldrin sum. Endrin also has not been detected and therefore is below the IJC objective level of 1.0 ng/L.

Other Contaminants

Heptachlor was detected in trace concentrations in 1974 (Glooschenko et al. 1976) but has not been otherwise observed. Heptachlor epoxide was reported in 1976-1977 (0.05 ng/L) at the mouth of the Saugeen River (Ont. Ministry of the

Environ. 1978), but it has not been noted elsewhere. The heptachlor-heptachlor epoxide sum falls below the IJC objective concentration of 1.0 ng/L.

Chlordane was not detected in Lake Huron until 1975 (MDNR 1957-1978), when the highest concentration of 1.0 ng/L was reported. Lower concentrations have been reported subsequently with all concentrations substantially lower than the IJC objective of 60.0 ng/L. Reports of chlordane are not specific, and although it may be assumed to be technical chlordane, concentrations of isomers or degradation products may have been reported.

Lindane was reported in the St. Marys River at 3.0 ng/L in 1967 (Lichtenberg et al. 1970). A single concentration of 0.5 ng/L was reported in 1975. Both reported concentrations are considerably less than the IJC concentration objective of 10.0 ng/L.

Alpha-BHC and cyanide were detected at only one site each, in the late 1960s, with no subsequent reports. Alpha-BHC was sought but not detected for a number of localities during the same time period.

Toxaphene was not detected in samples from several locations in 1967 and 1968 (Lichtenberg et al. 1970). It was not observed until 1980-1981 (Swain 1982). Swain's concentration of 1.6 ng/L was below the IJC objective level of 8.0 ng/L.

Phenols were reported to be present in several areas, with the highest mean concentration of 10.92 ng/L in the St. Marys River (Kinkead et al. 1976). The source of the high concentrations is believed to be the Algoma Steel Corporation Ltd. (ULRG 1977). Comparatively lower concentrations were observed in the Spanish River and were claimed to be derived from pulping operations near Espanola (ULRG 1977). Without further clarification of the specific chemical composition of the phenols reported, these records are of limited value. Phenol is a generic term referring to compounds which are hydroxy derivatives of benzene and its condensed nuclei. Most reports of phenols appear to refer to the results of non-specific phenol analyses such as proposed by the Environmental Protection Agency (USEPA 1979).

Dibutyl (DBP) and bis(2-ethylhexyl) phthalate (DEHP) were first reported in 1973 (Strachan 1976), when the highest dibutyl phthalate concentration (2,450.0 ng/L) in water was reported. A lower concentration (1,000.0 ng/L) was reported in 1976 for DBP (Ewing *et al*. 1977) for Saginaw Bay. DEHP data have been predominantly reported for Saginaw Bay (MDNR 1978, Ewing *et al*. 1977). Concentrations range from 1,000.0 to 2,250.0 ng/L. None of the reported concentrations exceed the 4,000.0 ng/L concentration objective proposed by the IJC for DBP. However, all observed concentrations of DEHP exceeded the IJC objective level of 600.0 ng/L.

A suite of contaminants has been reported sporadically to be present in Lake Huron water samples. These compounds, concentrations, and sources are listed below. Ewing *et al*. (1977) found: dimethyl sulfide 1,000.0 ng/L, dimethoxy methane 3,000.0 ng/L, chloroform 1,000.0 ng/L, dimethyl disulfide 1,000.0 ng/L, methyl palmitate 6,000.0 ng/L, methyl stearate 3,000.0 ng/L, terpene (C_{15}) 1,000.0 ng/L, and trace amounts of camphor in Saginaw Bay water. Frank *et al*. (1979) found the herbicides simazine 100 ng/L, atrazine 1,000.0 ng/L, and desethylatrazine 400.0 ng/L. Therefore, total atrazine was 1,000.0 ng/L at river mouths along the Canadian shores of Lake Huron. Filkins and Smith (1982) reported mean concentrations of pentachlorobenzene at 0.003 and 0.009 ng/L and hexachlorobenzene 0.002 and 0.004 ng/L for 1980 and 1981, respectively, in the open lake.

Numerous other contaminants have been sought but not detected, particularly organophosphorus pesticides. These compounds, their detection limits (LOD), and sources are presented below. Glooschenko _et al_. (1976) did not detect diazinon, ronnel, methyl parathion, malathion, parathion, ethion, dimethoate, or fenetrothion (LOD-0.005 ng/L); phorate, disulfoton (LOD-0.003 ng/L); crufomate (LOD-0.025 ng/L); imidan, azinphosmethyl, azinphosethyl (LOD-0.05 ng/L); phosphamidon (LOD-0.03 ng/L); methyl trithion, carbophenothion, p,p'methoxychlor, α and β endosulfan (LOD-0.01 ng/L). The Ontario Ministry of the Environment (1978) did not detect mirex or endosulfan in any of their water samples collected at the mouth of the Saugeen River.

Long-term Trends in Water Samples

Most organic contaminant data for the waters of Lake Huron are not suitable for trend analysis or analysis of variance tests. Factors contributing to this situation are a large occurrence of single samples, lack of continuous data, and varying or unknown sampling sites. Organic compounds which exceed the IJC concentration objectives are presented by compound and date (Table 3-2).

Table 3-2. Organic compounds and years when they exceeded the IJC concentration objectives in Lake Huron water samples.

COMPOUND	YEARS
PCB	1974, 1975, 1977, 1979, 1980
DDT	1974, 1975
Dieldrin-aldrin	1967
diethylhexyl phthalate	1974, 1976*

*most recent year parameter was sampled.

In samples which appear to be from open waters, PCBs rose from not detected in 1974 to its highest mean concentration in 1980. These higher 1980 concentrations were previously discussed in terms of their possible bias due to sediment resuspension. Mean concentrations from 1981 are an order of magnitude lower. PCB concentrations reported from Saginaw Bay are internally consistent with mean concentrations of 25.0 ng/L for 1977 and 1979, and a range of 0-23.0 ng/L for 1974. Nearshore localities showed great variation from site to site. PCB concentrations from the mouth of the Saugeen River were comparable to open lake values. However, concentrations at Harbor Beach were higher than open lake values by three orders of magnitude and were one order of magnitude higher than those of Saginaw Bay. Thunder Bay at Alpena also showed moderately high concentrations.

DDT-R was not detected or was found only in trace amounts for the open waters until 1974, when the highest concentrations were reported. Open water concentrations comparatively decreased by one, then two, orders of magnitude through 1981. High concentrations were also reported for Saginaw Bay and Thunder Bay in 1974.

Dieldrin was not detected or was reported as trace concentrations in the 1960s, with the exception of the highest concentration which was recorded in the St. Marys River in 1967. All subsequent dieldrin concentrations recorded were an order of magnitude less than the maximum observed in the St. Marys River. Aldrin and endrin were not detected.

Alpha BHC and lindane were found in high concentrations in 1967 but were not detected or were observed in greatly reduced concentrations since then. Toxaphene was not detected in 1967 and 1968 but was found in concentrations up to 1.6 ng/L in 1980. Phthalates were reported between 1973 and 1976 with slightly lower concentrations in 1976; however, there was no apparent trend.

Phenol concentrations vary greatly from site to site. Problems with chemically defining phenols have been previously discussed. However, assuming uniformity of analytical methods, concentrations appear to have decreased between the 1960s and 1970s in both the St. Marys River and the Canadian nearshore regions of the main lake. However, the tests used were implied to not be of great precision (Upper Lakes Reference Group 1977).

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CHAPTER FOUR

ORGANIC CONTAMINANTS IN LAKE HURON NET PLANKTON AND FILAMENTOUS ALGAE

Very limited data are available for organic contaminant levels in Lake Huron net plankton and filamentous algae (samples from 1974 and 1979 only), which points to the need for further surveillance studies. Most studies deal with the effects of particular organic compounds on algal growth but do not present concentrations contained in algal biomass. McNaught *et al*. (1982) conducted *in situ* experiments on the effects of PCBs on the growth of natural Lake Huron phytoplankton assemblages. Several culture studies have shown various effects of specific contaminants on Saginaw Bay phytoplankton growth (Lederman and Rhee 1981a, 1981b; Gotham and Rhee 1982). These studies have demonstrated that organic contaminant effects are compound and species specific, with effects ranging from growth stimulation to inhibition.

Algal assemblages are primary producers and one of the most fundamental elements of the trophic system. Because their growth is controlled by the absorption of ambient nutrients and substances from the water column, they are the interface between the medium and the remainder of the food chain (Stoermer 1978). Algae are usually most heavily grazed by zooplankton and other invertebrates, the next higher trophic level. Therefore, in some cases, they may introduce organic contaminants to the food chain and reflect conditions of the water column.

Contaminant data for plankton and filamentous algae are presented by algal group, location, and date (Table 4-1). Concentrations for plankton are derived from a combination of phytoplankton, zooplankton, and suspended solids collected

Table 4-1. Mean dry weight concentrations (ng/g) of organic contaminants detected in Lake Huron net plankton and filamentous green algae.

			PCB							
Group	n	Location	Total	% 1260	% 1254	% 1248	% 1242	p,p' DDE	Dieldrin	Source
Plankton										
1974 SLH	4	O	6,366.0					T	T	1
1974 SB	1	O	1,000.0					ND	T	1
1974 NLH	4	O	1,000.0					T	T	1
1974 GB	5	O(N)	3,340.0					T	T	1
1974 NC	1	N	1,000.0					ND	T	1
1979 HB	4	N	1,651.0		37.3		62.7	<5.0		2
Filamentous Algae										
Cladophora										
1979 HB	8	N	92.0		41.1		58.9	5.5		2
Ulothrix										
1979 HB	3	N	126.0		39.3		60.7	<1.0		2

Source Legend:

1. Glooschenko *et al*. (1976).
2. Anderson *et al*. (1982).

Location Key:

SLH = southern Lake Huron
SB = Saginaw Bay
NLH = northern Lake Huron
GB = Georgian Bay
NC = North Channel
HB = Harbor Beach, Michigan
N = nearshore
O = offshore
blank = no data
ND = not detected

by net tows. The filamentous algae described are somewhat better defined and are assigned to the algal genera Cladophora and Ulothrix.

PCBs were detected in 1974 and 1979 in Lake Huron plankton and ranged from 1,000.0 to 6,366.0 ng/g (Table 4-1). Highest concentrations are reported for 1974 in the southern basin of the lake, and next highest concentrations were found in Georgian Bay. These concentrations are perplexing when considering the distribution and potential sources of PCBs. These results may indicate new local sources of PCBs; however, this is unlikely. Very high concentrations were observed in southern Lake Huron plankton but not in Saginaw Bay or Harbor Beach plankton where discharges of PCBs are known to be occurring or where PCBs have a high ambient concentration (Chap. 3, this report). High concentrations were recorded in Georgian Bay which, in general, showed comparatively lower water concentrations than the aforementioned sites. A possible explanation for the higher residue levels in algae from relatively "clean" water is that the particle density is also lower at these sites and, therefore, there was less competition for the dissolved PCBs (Rice and Sikka 1973). The correlation of increasing partition coefficient (greater sorption capacity) with decreasing suspended solids concentration has been previously observed in aquatic systems (DiToro *et al*. 1982).

Dieldrin was detected in trace concentrations in all 1974 plankton samples. P,p'-DDE was found at trace levels in 1974 but was recorded as less than 5.0 ng/g in 1979.

Glooschenko *et al*. (1976) analyzed plankton samples for a large number of organochlorine and organophosphorus pesticides but did not detect them. A list of contaminants sought and the absolute detection limit are as follows: lindane, heptachlor, heptachlor epoxide, aldrin, p,p'-DDD, p,p'-DDT, o,p'-DDT

(LOD-1.0 ng); endrin, endosulfan I and II (LOD-10.0 ng); p,p'methoxychlor (LOD-50.0 ng). Organophosphorus pesticides that were sought but not detected are: phorate, disulfoton (LOD-50.0 pg); diazinon, ronnel, methyl parathion, malathion, parathion, ethion, dimethoate, fenitrothion (LOD-100.0 pg); methyl trithion, carbophenothion (LOD-220.0 pg); crufomate, phosphamidon (LOD-500.0 pg); imidan, azinphosmethyl, azinphosethyl (LOD-1000.0 pg).

The filamentous green algae Cladophora and Ulothrix are attached, macroscopic forms which are commonly observed in the Great Lakes. Cladophora grows prolifically to nuisance proportions in the lower Great Lakes and is extensive in the upper lakes. PCBs were detected in both algae with slightly lower concentrations reported for Cladophora (Table 4-1). Both are reported at concentrations of at least an order of magnitude less than plankton. Aroclor 1242 contributed the greatest percentage of PCB in both cases.

Para,para'-DDE was detected in Cladophora and Ulothrix (Table 4-1). Cladophora contained p,p'-DDE concentrations five-fold greater than did Ulothrix at the same locality. Concentrations of p,p'-DDE in Cladophora were comparable to concentrations in plankton also collected from the same site.

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CHAPTER FIVE

ORGANIC RESIDUES IN LAKE HURON FISH

The earliest record of organic contamination of Lake Huron fish was that of Reinert (1970) in 1966 where DDT-residues (DDT-R) were reported for nine fish species. In 1967, dieldrin was reported for additional Lake Huron fish (Reinert 1970). Also in 1967, the Bureau of Sport Fisheries and Wildlife established a national organochlorine insecticide monitoring program and reported several organic residues in four fish species from Saginaw Bay (Henderson *et al*. 1969). The National Pesticide Monitoring Program has continued to monitor fish for organochlorines in Lake Huron through the present; the results are presented in publications by Henderson *et al*. (1969), Henderson *et al*. (1971), Henderson *et al*. (1972), Schmitt *et al*. (1981), and Schmitt *et al*. (1983). The National Pesticide Monitoring Program (NPMP) data constitute one of the more extensive data sets available for Lake Huron fish. Samples for this data set were collected from Bayport, Michigan, in Saginaw Bay and offshore near Alpena, Michigan.

The Great Lakes Environmental Contaminants Survey (GLECS) was established in 1972 and also produced a data set of considerable size. Data from this survey were obtained through the participation of the Michigan Departments of Natural Resources, Agriculture, and Public Health, the U. S. Food and Drug Administration, the Michigan Water Resources Commission, and the U. S. Fish and Wildlife Service (Ann Arbor). This data set contains collections from 1972 through 1980 and is grouped by large lake regions (Fishery Statistical Districts) which are presented in Figure 5-1. A summary of the GLECS data was prepared by the Michigan Department of Natural Resources (MDNR) in a report by Forney (1982) and in a subsequent publication by Rohrer *et al*. (1982).

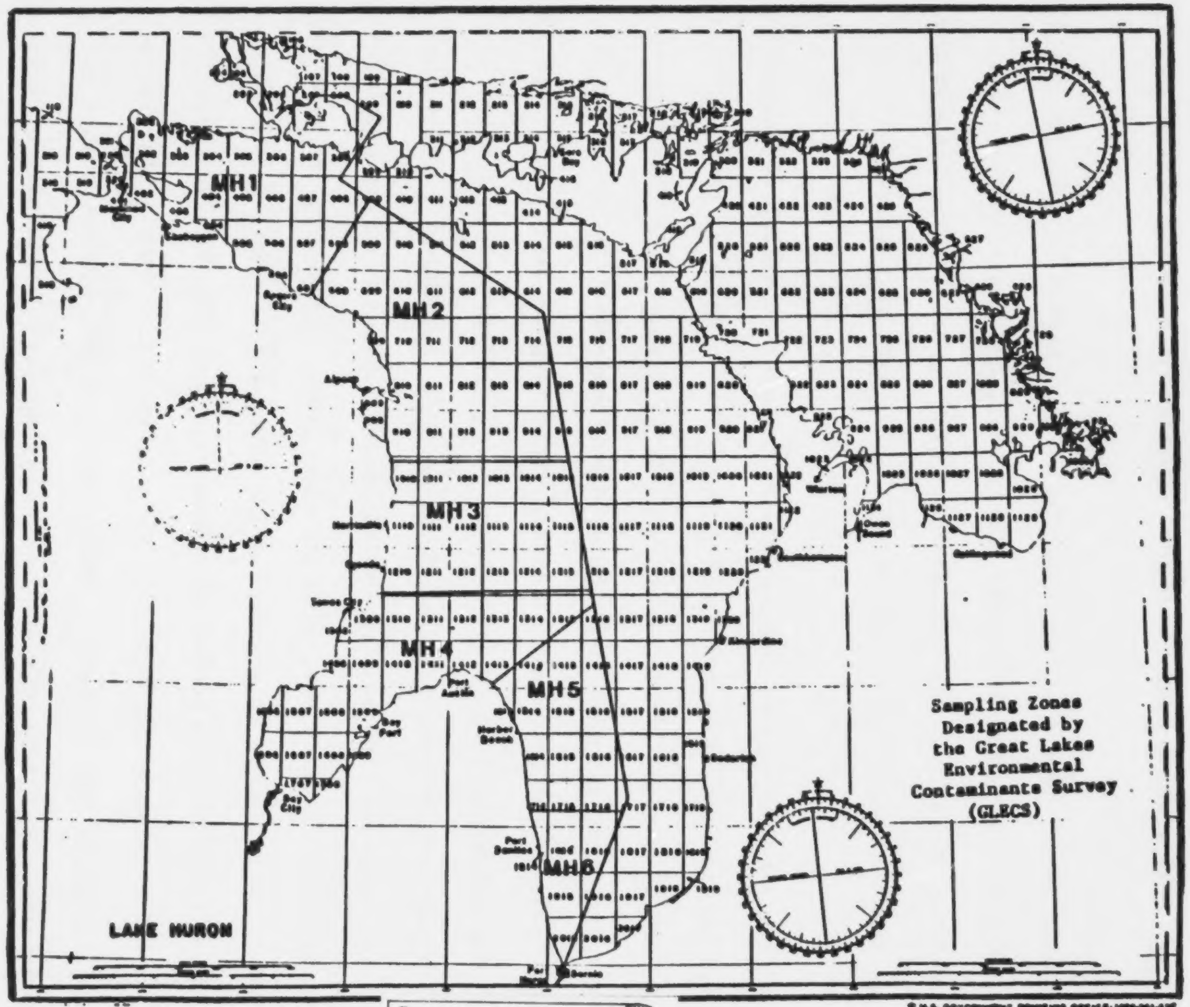
MH1
MH2
MH3
MH4
MH5
MH6
LAKE HURON
Sampling Zones
Designated by
the Great Lakes
Environmental
Contaminants Survey
(GLECS)

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Figure 5-1. Lake Huron fish sampling zones developed by the Great Lakes Environmental Contaminants Survey (GLECS).

Fish contaminant data from the Province of Ontario are provided by Environment Canada (1972-1977), the Ontario Ministry of the Environment (1976), and Fisheries and Oceans Canada (1977-1980). Another notable report is that by Frank et al. (1978) which contains a good compilation of early contaminant reports.

The most recent data available are for fish collected in 1980 (Forney 1982, Fisheries and Oceans Canada 1977-1980, Clark 1981, and Clark et al. 1982). Organic residue concentrations in Lake Huron fish apparently lie between the ranges of organic contaminants reported for the other Great Lakes (Delfino 1979).

The data set for organic residues found in Lake Huron fish is surprisingly large even though Lake Huron has lagged behind the other Great Lakes in sampling frequency and intensity. As is common with large data sets of this type to which many different agencies contribute, exact comparability is seldom achieved. Some of the prominent factors contributing to data set incompatibility are: the number of samples or analyses made, differences in sample localities, fish preparation methods, analytical methods, species captured, times of year for collections, fish feeding habits, migration characteristics, inter- and intra-species fat content, sex, age, and size class. These aspects have been discussed in relationship to organochlorine monitoring by Phillips (1978).

Some of these factors become more prominent when the data are closely inspected. For example, the year for the most extensive data collection was 1974 (approximately 644 analyses). When comparing mean concentrations for this year with other years, the 1974 results always appear to be middle-of-the-road, due to the large sample size. When obtaining yearly means, outlier data points are tempered by the large number of samples. The inverse occurs for years with smaller sampling sizes, when extremes are present in the data set. Certainly, the larger sample size is preferred and is probably more accurate in estimating conditions.

Certain regions or particular species cannot be adequately addressed due to inconsistent sampling sites. For example, the highest mean DDT-R concentration for lake trout was observed in 1969 for fish captured in Georgian Bay. Since then, no other lake trout have been captured in Georgian Bay for comparison. Similarly, residue data for channel catfish are reported only from Saginaw Bay; and, therefore, comparisons from region to region cannot be made. In this review, contaminant data have been segmented by species, by large lake regions (e.g., Saginaw Bay, the North Channel, Georgian Bay, and open lake) and, in some cases, by smaller areas of the lake (e.g., the southern, central, and northern basins and specific nearshore zones).

Variation of organic concentrations in different tissues and anatomical regions of mullet was investigated by Zabik et al. (1978). When reported on a wet-weight basis, the fattier portions (head, lateral line, etc.) had higher concentrations of dieldrin, DDT, and PCB than the other portions. In terms of general fish sections, the head region had the greatest concentrations of organics with lower concentrations found for the middle and tail sections, corresponding to the amount of fat present. However, on a fat basis, distribution over the anatomical regions was more uniform. Comparing specific tissues, high concentrations were observed in the belly flap tissue and medial muscle. Ventral muscle had somewhat lower concentrations, with the dorsal muscle showing distinctly lower concentrations. These data show that large differences in organic concentrations exist between tissues and anatomical regions of a single fish and that differences resulting from different fish preparation methods (e.g., edible portion vs. whole fish) are expected. Other factors which may produce inconsistent data will be pointed out in the following sections.

Organic Contaminant Levels in Lake Huron Fish

Available data on organic contaminants detected in Lake Huron fish encompass the years 1966 through 1980 (Table 5-1). Data are presented as analyses of individual fish or of several specimens. Yearly mean concentrations for individual species, composed of average concentrations for a single species during a particular year, are also discussed and presented in some figures. Error estimates are presented when available. A list of scientific and common names is presented for fish reported in this study (Table 5-2). Although there are obvious nomenclatural problems and, in many cases, inadequate or incomplete fish identifications, there has been no attempt by the present authors to reinterpret identifications, and names are presented as originally published.

PCBs

The single highest mean PCB concentration of 9.47 mg/kg was detected in Saginaw Bay common carp fillets in 1980 (Forney 1982). Other high individual means were observed for chinook salmon in 1973 (9.2 mg/kg) and Saginaw Bay channel catfish (8.16 mg/kg) in 1973 (Forney 1982).

PCB concentrations in Saginaw Bay common carp, as reported by the National Pesticide Monitoring Program (NPMP) and the Michigan Department of Natural Resources (MDNR), show similar trends, even though the fish preparation methods differ (Fig. 5-2). NPMP reports the results of whole fish analyses; whereas, MDNR reports analyses of skinless fillets. Both show high concentrations of 5.5 mg/kg (NPMP) and 4.1 mg/kg (MDNR) in 1971 and 1972, respectively, with

Table 5-1. Mean concentrations (mg/kg) of the major organic contaminants detected in Lake Huron fish, 1966-1980.

					P C B					D D T																	
	# analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1966																											
Alewife	3(11)									2.44																	1
American smelt	3(28)									0.75																	1
Bloater	1(4)									3.60																	1
Channel catfish	1(1)									6.90																	1
Lake whitefish	1(1)									2.43																	1
Sea lamprey	1(1)									1.27																	1
Walleye	1(1)									6.02																	1
White sucker	1(1)									1.14																	1
Yellow perch	6(30)									1.59																	1
1967																											
Alewife	2(10)																0.05										1
American smelt	2(14)																0.04										1
Bloater	1(4)																0.11										1
Channel catfish	1(1)																0.07										1
Lake whitefish	1(1)																0.12										1
Sea lamprey	1(1)																0.02										1
Walleye	1(1)																0.08										1
White sucker	1(1)																0.02										1
Yellow perch	3(13)																0.03										1
Carp	2(11)	SB	0.80							2.50	32.3		55.4		12.4		0.02	ND	.08						ND		2
White sucker	1(6)	SB	0.70							1.70	35.3		64.7		ND		0.01	ND	ND						ND		2
Channel catfish	2(11)	SB	0.58							3.11	49.2		46.4		4.4		0.29	ND	ND						ND		2
Yellow perch	2(16)	SB	0.35							1.66	56.5		35.5		8.1		0.04	ND	ND						ND		2

(continued)

Table 5-1. (Continued).

					P C B					D D T																
	n analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1968																											
Smallmouth bass	3	O	0.50	3.1	0.9					1.97	34.5		38.6		26.9		0.01										3
Yellow perch	5	O	0.36	0.8	0.2					0.52	38.5		23.1		36.5		0.01										3
Walleye	3	O	0.41	0.8	0.1					0.29	41.4		13.8		44.6		0.01										3
Coho salmon	8	O	0.08	3.9	0.5					0.26	42.0		11.5		46.2		0.01										3
Kokanee salmon	2	O	0.10	3.5	0.3					1.15	38.3		10.4		51.3		0.04										3
Rainbow trout	12	GB	0.86	5.5	0.3					1.75	42.3		9.7		48.0		0.04										3
Carp	2(10)	SB	1.52							0.68	43.7		43.0		13.3		0.01	ND	ND							ND	2
Channel catfish	2(8)	SB	1.03							3.35	38.6		35.3		26.1		0.04	ND	ND							ND	2
Yellow perch	2(10)	SB	0.29							0.93	35.1		42.2		22.7		0.01	ND	0.14							ND	2
1969																											
Yellow perch	20	NC	0.20	1.4	0.01					0.07	42.9		14.3		42.9		0.01										3
Walleye	15	GB	2.07	2.6	1.5					2.37	44.3		10.1		45.6		0.02										3
Bloater	15	O	0.10	3.0	0.2					0.69	56.5		17.4		26.1		0.01										3
Cisco	2	O	0.18	5.4	0.1					0.61	57.4		8.2		34.4		0.01										3
Cisco	10	GB	0.82	7.2	0.5					1.59	25.8		11.9		62.3		0.01										3
Coho salmon	5	O	1.89	5.8	0.6					1.52	57.9		10.5		31.6		0.03										3
Kokanee salmon	11	O	0.10	3.3	0.1					0.23	43.8		13.0		43.8		0.01										3
Splake	20	G	1.11	6.3	0.2					1.03	41.7		13.6		44.7		0.04										3
Splake	(3)	O	0.82	6.8	0.2					1.61							0.06										3
Splake	(5)	O	1.35	6.9	0.3					0.86							0.03										3
Lake trout	4	GB	6.33	13.4	0.7					7.60	53.2		6.6		43.3		0.07										3
Lake whitefish	20	NC	1.43	4.8	0.1					0.56	23.2		12.5		64.3		0.06										3
Lake whitefish	26	O	0.71	5.0	0.1					0.36	36.1		13.9		50.0		0.04										3
Lake whitefish	10	GB	1.05	4.0	0.2					0.51	39.2		17.6		43.1		0.01										3
Lake whitefish	22	O	0.73	5.4	0.1					0.40							0.05										3
Lake whitefish	(1)	O	1.18	3.7	0.1					0.25							0.03										3
Lake whitefish	(6)	NC	0.94	3.2	0.1					0.14							0.01										3
Lake whitefish	(8)	NC	1.19	6.1	0.1					0.89							0.10										3
Lake whitefish	(4)	GB	0.94	4.5	0.1					0.44							0.01										3
Lake whitefish	(6)	GB	1.13	3.7	0.2					0.54							0.01										3
Carp	1(5)	SB	1.0	11.7	1.70		100.0			0.67	34.5		49.4		16.1		0.02	0.00						0.04		0.05	4,5
Channel catfish	1(5)	SB	.7	14.8	4.00		100.0			1.86	37.2		41.0		21.6		0.06	0.00						0.29		0.13	4,5
Yellow perch	1(5)	SB	.2	3.6	4.02		100.0			1.52	31.6		44.7		23.6		0.02	0.00						0.02		0.09	4,5

(continued)

Table 5-1. (Continued).

					P C B					D D T																	
	n analysis # of fish	Location	Mean weight(kg)	Mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1970																											
Coho salmon	3	O								10.5	56.5		10.5		24.8	6.3	ND										7
Coho salmon	4	GB								8.15	59.8		11.0		19.9	7.1	0.24										7
Coho salmon	3	O								1.26	38.8		12.1		39.1	12.4	0.08										7
Whitefish	3	O								0.83	27.7		6.6		46.2	14.5	0.14										7
Whitefish	2	O								1.47	28.2		9.2		49.0	13.6	0.23										7
Kokanee salmon	1	O								1.30	36.5		7.7		46.2	7.7	0.20										7
Yellow pickeral	1	O								0.47	40.4		10.6		36.3	8.5	0.01										7
Yellow pickeral	1	GB								4.29	39.2		10.7		43.6	6.5	0.15										7
Sturgeon	1	O								0.62	51.6		19.4		29.0	ND	ND										7
Yellow perch	1	GB								1.46	29.5		9.6		51.4	9.6	0.03										7
Mullets	1	GB								2.99	30.1		12.7		46.5	8.7	0.14										7
Chub	1	O								3.08	23.4		10.1		51.6	14.9	0.31										7
Rainbow trout	1	GB								2.02	29.7		10.9		43.6	15.6	0.17										7
Carp	1(5)	SB	1.8	15.8	2.76		100.0			1.23	47.2		41.5		11.4		0.02	0.00						0.31		0.07	8,5
Channel catfish	1(5)	SB	0.6	15.5	3.80		100.0			2.03	44.3		35.0		20.7		0.03	0.00						0.09		0.07	8,5
Yellow perch	2(10)	SB	0.1	3.3	3.33		100.0			1.44	38.9		36.1		25.0		0.01	0.00						0.02		0.08	8,5
Alewife	8(21)	O	0.03	7.5	1.1					1.63	46.6		14.1		61.5		0.06										3
Rainbow smelt	8(21)	O	0.02	6.5	0.7					0.80	45.0		15.0		40.0		0.04										3
Rainbow smelt	5(24)	NC	0.03	3.6	0.1					0.31	38.7		12.9		48.4		0.02										3
Walleye	2	O	2.08	10.1	1.3					5.05	46.9		12.7		40.4		0.08										3
Walleye	21	GB	3.24	4.7	1.4					2.15	43.7		10.7		45.6		0.04										3
Walleye	3	NC	0.61	2.1	0.1					0.39	46.7		10.3		41.0		0.01										3
Bloater	10	O	0.26	16.0	2.6					4.68	41.7		10.5		47.9		0.16										3
Coho Salmon	41	O	1.03	4.9	0.6					0.98	49.0		11.2		39.8		0.04										3
Kokanee Salmon	15	O	0.51	4.1	0.6					0.95	40.0		12.6		47.4		0.04										3
Splake	23	O	0.81	10.2	1.0					1.00	37.0		13.0		50.0		0.04										3
Splake	(3)	O	0.78	13.2	1.6					1.16							0.06										3
Splake	(8)	O	1.22	17.6	1.5					1.35							0.07										3
Lake whitefish	3	NC	1.18	9.9	0.4					0.74	36.5		9.5		54.1		0.06										3
Lake whitefish	(1)	NC	0.98	8.6	0.4					0.80							0.15										3
Lake whitefish	(2)	NC	1.29	10.6	0.4					0.71							0.07										3

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(continued)

Table 5-1. (Continued).

					P C B					D D T																	
	n analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1969-76																											
Yellow perch	(4)	O			0.15					0.06																	6
Yellow perch	(2)	SB			0.13					0.04																	6
Yellow perch	(1)	O			0.02					0.03																	6
Carp	(3)	SB			1.33																						6
Carp	(2)	O			1.84																						6
1969-75																											
Carp	(4)	SB								0.47																	6
Carp	(1)	O								0.22																	6
Carp	(1)	O								0.72																	6

(continued)

Table 5-1. (Continued).

	n analysis # of fish	Location	mean weight(kg)	mean % lipids	PCB Total	PCB % 1260	PCB % 1254	PCB % 1248	PCB % 1242	DDT DDT-R	DDT % p,p'DDE	DDT % o,p'DDE	DDT % p,p'DDD	DDT % o,p'DDD	DDT % p,p'DDT	DDT % o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1971																											
Walleye	10	GB	2.86	5.8	1.8					3.06	56.9		6.9		36.3		0.03										3
Bloater	6	0	0.07	15.0	2.2					4.71	58.0		6.2		35.9		0.05										3
Bloater	4(12)	GB	0.26	20.1	5.2					5.18	56.0		10.2		33.6		0.22										3
Coho Salmon	10	0	0.94	6.0	1.0					1.15	43.5		17.4		39.1		0.06										3
Carp	2(10)	SB	1.2	9.7	5.50		100.0			0.65	55.8		32.6		11.6		0.02	0.00								0.00	8
Channel catfish	2(10)	SB	0.8	17.5	1.54		100.0			1.38	56.2		26.4		17.4		0.05	0.00								0.00	8
Yellow perch	2(10)	SB	0.2	3.0	2.84		100.0			0.47	49.2		33.3		17.2		0.01	0.00								0.00	8
1972																											
White sucker	5	0	0.72	2.5	0.1					0.11	72.7		9.1		18.2		0.01										3
Smallmouth bass	5	0	0.35	3.7	0.4					0.16	75.0		6.3		16.8		0.01										3
Smallmouth bass	6	GB	0.28	2.8	0.01					0.07	71.4		14.3		14.3		0.01						ND				3
Yellow perch	5	0	0.07	4.4	0.1					0.11	63.6		9.1		27.3		0.01						ND				3
Splake	5	0	0.54	8.5	0.5					0.62	48.4		6.5		45.2		0.03						T				3
Splake	(3)	0	0.79	10.8	0.7					0.87							0.05										3
Lake whitefish	25	0	0.76	8.2	0.04					0.55	50.9		27.3		40.0		0.06						ND				3
Lake whitefish	(12)	0	0.81	8.2	0.3					0.55							0.07										3
Lake whitefish	(7)	0	1.14	12.3	0.6					0.87							0.09										3
Lake whitefish	(5)	MH-3	1.36	ND	0.50					0.40							0.04									0.06	9
Lake whitefish	(3)	MH-4	1.15	ND	0.64					0.32							0.02									0.02	9
Coho salmon	(11)	MH-4	1.80	ND	3.04					1.07							0.02									0.37	9
Yellow perch	(6)	MH-4	0.16	ND	0.25					0.01							0.01									0.09	9
Carp	(6)	MH-4	4.10	ND	4.10					1.1							0.05									0.13	9
Coho salmon		0			5.4					1.5							0.05										10
Walleye		0			0.47					0.19							0.02										10

(continued)

Table 5-1. (Continued).

	n analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
					P C B					**D D T**																	
1973																											
White sucker	4	GB	0.13	0.7	0.1					0.01							0.01										3
Splake	26	O	0.56	8.8	0.4					0.47	80.9		6.4		12.8		0.03										3
Splake	(10)	O	0.69	6.6	0.6					0.77							0.03										3
Splake	(4)	O	1.11	4.4	0.9					0.75							0.06										3
Lake whitefish	19	O	0.80	14.2	0.04					0.47	48.9		10.6		40.4		0.06										3
Lake whitefish	(7)	O	1.17	17.1	0.4					0.64							0.08										3
Carp	1(5)	SB	0.80	7.0	4.3	23.3	0.00		76.7	0.16	100.0						0.00	0.00							0.00		8
Channel catfish	1(5)	SB	0.60	29.5	6.6	27.3	0.00		72.7	0.56	41.1		56.9		0.00		0.00	0.00							0.00		8
Yellow perch	2(10)	SB	0.20	4.3	4.3	40.7	0.00		59.3	0.19	100.0		0.00		0.00		0.02	0.00							0.00		8
Brown trout	(6)	MH-2	3.71	ND	3.59					2.21							0.06									0.24	9
Lake whitefish	(18)	MH-1	1.13	ND	0.50					0.60							0.09									0.07	9
Chinook salmon	(5)	MH-3	8.42	ND	9.2					5.8							0.20									0.27	9
Walleye	(6)	MH-1	ND	ND	1.1					0.9							0.04									0.55	9
Yellow perch	(6)	MH-1	ND	ND	0.22					0.08							0.01									0.16	9
Channel catfish	(37)	MH-4	1.31	ND	8.16					3.82							0.08									0.25	9
Walleye		O			0.40					0.13							0.01										10
Coho salmon		O			3.5					1.4							0.11										10

(continued)

Table 5-1. (Continued).

	# analysis # of fish	Location	mean weight(kg)	mean % lipids	P C B					D D T																
					Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1974																											
Splake	1	O	1.24	4.1	0.2					0.15	73.3		6.7		20.0		0.02										3
Splake	(1)	O	0.53	3.3	0.1					0.11							0.01										3
Splake	(4)	O	1.27	4.4	0.3					0.15							0.02										3
Carp	1(5)	SB	1.4	12.0	2.4	0.00	100.0		0.00	0.44	81.8		18.2		0.00		0.00	0.00							0.00		8
Channel catfish	1(5)	SB	0.9	13.4	4.7	0.00	100.0		0.00	0.66	42.4		51.5		6.1		0.08	0.00							0.00		8
Yellow perch	2(10)	SB	0.2	4.9	3.1	0.00	100.0		0.00	0.87	69.0		12.6		18.4		0.03	0.00							0.00		8
Lake whitefish	1(5)	AL	0.8	10.0	0.51	0.00	100.0		0.00	0.22	100.0		0.00		0.00		0.00	0.00							0.00		8
White sucker	1(5)	AL	1.0	5.3	0.46	0.00	100.0		0.00	0.15	46.7		33.3		20.0		0.03	0.00							0.00		8
Yellow perch	2(10)	AL	0.3	5.5	0.69	0.00	100.0		0.00	0.43	64.7		23.5		11.8		0.02	0.00							0.00		8
Bloater	10(53)	DI	0.27	21.0	1.25					1.46	48.0	4.1	8.2		26.6	11.0	0.18									0.05	11
Bloater	10(42)	LI	0.12	9.0	0.89					2.17	51.2	1.4	5.1		35.0	7.4	0.08									0.17	11
Bloater	10(14)	AL	0.19	21.0	2.61					4.37	47.0	1.8	5.5		36.6	9.2	0.20									0.10	11
Bloater	10(29)	MI	0.23	22.0	1.68					3.52	46.0	2.0	6.8		33.5	9.7	0.29			0.49				0.04		0.11	11
Bloater	10(50)	GH	0.28	20.0	1.48					2.75	36.4	10.2	9.5		31.3	12.0	0.38			0.30				0.03		0.06	11
Slimy sculpin	10(51)	DI	0.02	6.0	0.52					0.60	33.3	5.0	10.0		35.0	16.7	0.14									0.06	11
Slimy sculpin	10(47)	LI	0.02	5.0	0.71					0.76	44.7	1.3	5.3		40.8	7.9	0.07									0.12	11
Slimy sculpin	10(50)	HB	0.01	6.0	0.77					0.65	32.3	4.6	12.3		38.5	12.3	0.11									0.08	11
Slimy sculpin	10(44)	AL	0.01	6.0	0.55					0.65	33.9	6.2	9.2		38.5	10.8	0.14									0.08	11
Slimy sculpin	10(72)	MI	0.01	8.0	0.81					0.66	36.4	4.5	12.1		33.6	13.6	0.14			0.17				0.03		0.07	11
Burbot	10(15)	LI	0.37	5.0	0.81					1.04	50.0	1.9	10.6		26.6	7.7	0.07									0.11	11
Burbot	10(50)	MI	2.4	7.0	2.35					1.77	56.5	1.0	8.5		29.4	5.6	0.12		T	0.18	T T	T	T	0.01	T	0.18	11
Burbot	10(52)	GH	0.47	5.0	0.77					0.53	41.5	5.7	15.1		30.2	7.6	0.08		ND	0.14	T T	ND	T	0.04	ND	0.06	11

(continued)

Table 5-1. (Continued).

	n analysis # of fish	Location	mean weight(kg)	mean % lipids	P C B					D D T																	
					Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1974 (continued)																											
Brown trout	(6)	MH-1	2.3		0.72					0.45							0.02									0.12	12
Yellow perch	(36)	MH-1			0.00					0.00							0.00									0.26	12
Yellow perch	(46)	MH-4			0.09					0.03							0.00									0.08	12
Suckers	(4)	MH-4			0.38					0.07							0.00									0.04	12
Brown trout	1	AL			1.10					0.50							0.04						ND			0.13	13
Chinook salmon	1	AL			2.31					0.97							0.05						ND			0.22	13
Perch	2	NB			0.22					0.09							ND						ND			0.34	13
Perch	10(50)	GH			0.09					0.02							0.002	ND								0.22	14
Perch	40(200)	GB			0.15					0.03							0.003	ND								0.28	14
Perch	30(150)	NC			0.09					0.01							0.001	ND								0.27	14
Rainbow trout	20(100)	GH			2.06					0.52							0.04	ND								0.17	14
Rainbow trout	30(150)	GB			1.06					0.38							0.03	ND								0.19	14
White sucker	20(100)	GH			0.48					0.19							0.02	ND								0.19	14
White sucker	30(150)	GB			0.80					0.46							0.04	ND								0.12	14
White sucker	30(150)	NC			0.15					0.05							0.004	ND								0.07	14
Northern pike	10(50)	GH			0.52					0.15							0.004	ND								0.40	14
Northern pike	30(150)	NC			0.16					0.04							0.001	ND								0.22	14
Walleye	20(100)	GB			0.54					0.23							0.007	ND								0.52	14
Rock bass	10(50)	GB			0.07					0.01							0.002	ND								0.17	14
Walleye		O			0.94					0.32							0.01										10

(continued)

Table 5-1. (Continued).

					P C B					D D T																
	# analysis # of fish	Location	mean weight (kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1974 (continued)																											
Brown trout	(3)	MH-1	1.39	ND	1.13					0.57							0.02									0.13	9
Brown trout	(3)	MH-2	0.92	ND	0.26					0.21							0.02									0.06	9
Brown trout	(3)	MH-3	3.40	ND	1.93					0.79							0.05									0.20	9
Rainbow trout	(3)	MH-1	1.27	ND	0.33					0.32							0.02									0.10	9
Lake whitefish	(18)	MH-1	1.16	4.7	0.11					0.26							0.05									0.04	9
Lake whitefish	(9)	MH-2	1.34	4.7	0.34					0.35							0.05									0.03	9
Lake whitefish	(9)	MH-3	1.04	ND	0.22					0.12							0.03									0.02	9
Walleye	(12)	MH-1	0.74	ND	0.02					0.03							0.01									0.17	9
Yellow perch	(10)	MH-1	0.19	0.23	0.02					0.01							0.01									0.31	9
Yellow perch	(6)	MH-2	0.19	0.25	0.04					0.03							0.02									0.15	9
Yellow perch	(4)	MH-4	0.14	0.28	0.11					0.04							0.01									0.10	9
Carp	(8)	MH-4	1.93	6.9	2.3					0.58							0.01									0.06	9
1974-75																											
Yellow perch	(4)	O																								0.26	6
Yellow perch	(5)	O																								0.24	6
Yellow perch	(2)	SB																								0.11	6
Carp	(6)	SB																								0.08	6
Coho salmon	(1)	O			3.54																					0.34	6
Chinook salmon	(1)	O			2.97					1.39																0.21	6
Chinook salmon	(1)	O			2.31																					0.22	6
Brown trout	(3)	O			1.17					0.97																0.10	6
Brown trout	(5)	O			1.44					0.81																0.10	6
Rainbow trout	(1)	O			0.94					0.46																0.13	6
Rainbow trout	(5)	O			0.50					0.41																0.15	6

(continued)

Table 5-1. (Continued).

					P C B					D D T																	
	# analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1975																											
elt	(3)	MH-1	ND		0.73					0.38							0.01									0.19	12
ickers	(6)	MH-1	ND		0.64					0.39							0.09									0.04	12
Perch	(1)	AL			0.13					0.04							ND						ND			0.26	13
Perch	(1)	SB			0.20					0.07							ND						ND			0.27	13
Smallmouth bass	9	GB	0.36	3.2	0.6					0.21	81.0		4.8		14.3		0.03		ND	0.01							3
Yellow perch	10	MC	0.18	6.1	0.9					0.48	75.0		6.3		18.6		0.05										3
Walleye	10	O	2.54	4.7	0.5					0.70	54.3		7.1		38.6		0.03		ND	0.05							3
Bloater	10	GB	0.22	16.3	2.2					1.43	49.7		11.2		39.2		0.30										3
Bloater	20	MC	0.29	22.9	2.6					1.87	62.0		9.1		26.9		0.29										3
Cisco	6	GB	0.54	18.0	2.2					1.51	51.7		9.9		38.4		0.19										3
Coho salmon	11	O	2.28	5.8	1.3					0.53	81.1		9.4		9.4		0.08										3
Splake	2	O	2.13	17.2	6.0					2.68	67.2		15.7		18.7		0.48										3
Splake	17	GB	1.05	13.3	1.6					0.78	66.7		10.3		23.1		0.15										3
Splake	(6)	GB	0.75	11.9	1.4					0.78							0.14										3
Splake	(6)	GB	1.19	14.1	1.9					0.87							0.16										3
White mullet	(4)	SB		1.98	0.48					0.04							0.07										15
Redhorse mullet	(1)	SB		5.5	0.18					0.04							0.05										15
White mullet	(4)	SB		2.21	0.50					0.13							0.10									0.08	15
Redhorse mullet	(1)	SB		7.9	0.70					0.08							0.11									0.07	15
Chinook salmon	(7)	MH-3	2.00		1.38					0.63							0.04									0.00	16
Lake trout	(18)	MH-1	1.01	7.1	1.38					0.83							0.05									0.13	9
Lake trout	(1)	MH-5	2.50	ND	5.70					0.52							0.06									0.37	9
Brown trout	(6)	MH-2	1.39	5.4	1.08					0.54							0.03									0.12	9
Lake whitefish	(9)	MH-1	1.05	4.3	0.23					0.19							0.05									0.06	9
Lake whitefish	(8)	MH-3	1.21	4.1	0.38					0.23							0.06									ND	9
Carp	(8)	MH-4	2.38	ND	1.6					0.29							0.01									0.06	9
Carp	(12)	MH-5	1.81	ND	1.22					0.30							0.01									0.14	9
1975-76																											
Lake trout	(5)	O			2.01					1.60																0.27	6

(continued)

Table 5-1. (Continued).

					P C B					D D T																
	# analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1976																											
White mullet	(1)	SB		2.30	0.15					0.08							0.04									0.05	15
White mullet	(1)	SB		2.95	0.17					0.10							0.07										15
White sucker	10	O	0.98	0.6	0.1					0.09	66.7		11.2		22.2		0.01		T	T							3
Alewife	5(23)	O	0.02	10.7	0.3					0.80	55.0		12.5		32.5		0.14		0.03	0.04							3
Rainbow smelt	7(32)	O	0.01	2.7	0.01					0.15	73.3		13.3		13.3		0.01		T	T							3
Yellow perch	17	O	0.24	2.5	0.2					0.32	65.6		9.4		25.0		0.02		T	T							3
Cisco	9(11)	GB	0.14	5.0	0.2					0.20	70.0		25.0		5.0		0.03		0.01	0.03							3
Lake whitefish	15	B	1.32	5.8	0.2					0.13	61.5		15.4		23.1		0.06		0.05	0.03							3
Lake whitefish	(2)	O	0.85	3.7	0.1					0.08							0.03										3
Lake whitefish	(10)	O	1.24	6.1	0.2					0.12							0.07										3
Lake trout	(18)	MM-1	1.12	7.0	1.86					1.36							0.16									0.25	9
Lake trout	(5)	MM-3	1.5	10.1	1.53					1.22							0.07									0.23	9

(continued)

Table 5-1. (Continued).

					P C B					D D T																	
	n analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1977																											
Carp	2(10)	SB	1.5	10.6	2.8	25.0	46.4	28.6	0.00	0.71	78.0		22.0		0.00		0.02	0.00		0.03/ 0.00	0.00/ 0.01		0.01	0.02	0.00	0.14	17
Yellow perch	2(10)	SB	0.1	3.7	2.2	29.5	43.2	27.2	0.00	0.26	70.6		17.6		11.6		0.01	0.00		0.02/ 0.00	0.00/ 0.05		0.02	0.01	0.35	0.03	17
Lake trout	1(5)	AL	2.0	25.9	4.60	50.0	26.3	21.7	0.00	2.61	71.6		16.5		11.6		0.04	0.01		0.02/ 0.00	0.00/ 0.02		0.03	0.03	9.00	0.07	17
White sucker	3(15)	AL	0.87	6.5	0.80	75.0	25.0	0.00	0.00	0.21	63.5		19.0		17.5		0.03	T		0.01/ 0.00	0.00/ 0.01		T	0.01	0.33	0.24	17
Lake trout	4(20)	AL	0.73		1.46					1.50	31.7	5.1	13.1	2.9	24.3	22.9	0.34	T		0.22		0.03					18
Lake trout	4(20)	AL	2.0		1.98					1.77	49.8	6.2	8.9	1.1	18.8	15.3	0.27	T		0.25		0.04					18
Lake trout	(11)	MH-1	1.06	6.3	1.94					0.97							0.04									0.24	9
Lake trout	(17)	MH-2	1.71	6.7	1.83					0.27							0.01									0.22	9
Lake trout	(9)	MH-3	2.20	10.1	2.02					1.81							0.08									0.23	9
Lake trout	(6)	MH-4	1.60	9.3	2.82					2.70							0.10									0.23	9
Lake trout	(19)	MH-5	2.35	15.3	2.46					0.92							0.09									0.25	9
Channel catfish	(12)	MH-4	0.69	8.3	2.56					0.55							0.03									0.17	9
Carp	(6)	MH-4	2.41	9.0	1.64					0.23							0.02									0.09	9
Carp	(2)	SB								0.22																	6
1977-78																											
Lake trout	(4)	SB			2.62					1.96																0.24	6
Lake trout	(10)	O			2.08					1.10																0.24	6
Carp	(3)	SB																								0.09	6
Yellow perch	(1)	SB			0.45					0.03																0.06	6
Round whitefish	19(82)	SB			0.54					0.14							0.001										19
1977-79																											
Channel catfish	(9)	SB			3.75					1.89																	6
Carp	(4)	SB			2.21																						6

(continued)

Table 5-1. (Continued).

					P C B					D D T																
	n analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1978																											
Lake trout	4(20)	AL	0.73		1.65					0.88	49.1	4.9	7.0	7.3	16.0	15.8	0.14	0.01		0.14		0.02					18
Lake trout	4(20)	AL	2.0		2.64					2.22	50.3	3.3	5.2	12.2	16.9	12.2	0.27	0.01		0.25		0.04					18
Lake trout	4(20)	AL	3.6		3.07					2.25	59.5	3.4	7.0	3.0	14.1	13.1	0.29	T		0.26		0.04					18
Lake trout	(6)	MH-1	1.4	6.1	0.81					0.66							0.05									0.21	9
Lake trout	(6)	MH-4	3.0	13.1	2.73					1.09							0.04									0.31	
Bloater	(12)	MH-4	0.36	13.4	0.41					1.06							0.20									0.08	
Walleye	(6)	MH-1	0.43	1.12	0.43					0.33							0.02									0.69	
Yellow perch	(10)	MH-4	0.19	ND	0.39					ND							ND									0.15	
Channel catfish	(16)	MH-4	ND	ND	3.23					0.83							0.07									0.28	
Carp	(5)	MH-4	5.3	11.4	3.59					0.09							0.01									0.08	
Perch	(2)	SB			0.09																						
Catfish	(1)	SB			2.10																						20

(continued)

Table 5-1. (Continued).

					P C B					D D T																	
	# analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1979																											
Lake trout	4(20)	AL	0.73		1.37					0.96	37.3	6.4	9.9	1.5	29.0	16.0	0.15	0.005		0.14		0.02					18
Lake trout	4(20)	AL	2.0		2.94					1.74	55.0	2.6	6.7	2.0	16.1	17.6	0.31	0.02		0.25		0.03					18
Lake trout	4(20)	AL	3.6		3.94					3.21	52.5	6.0	8.5	2.2	15.1	15.7	0.50	T		0.35		0.07					18
Carp	2(10)	SB	1.3	10.7	5.25	30.5	70.5	0.00		0.67	79.7		20.3		0.00		0.02	0.03		0.04/ 0.01	0.01/ 0.03	0.00	0.00	0.01	2.01	0.00	17
Yellow perch	1(5)	SB	ND	2.4	0.67	10.4	89.6	0.00		0.15	80.0		20.0		0.00		0.01	0.00		0.01/ 0.00	0.01/ 0.01	0.00	0.00	0.00	0.20	0.00	17
White sucker	2(10)	AL	0.6	5.5	0.85	52.9	47.1	0.00		0.18	80.0		0.00		20.0		0.02	0.00		0.01/ 0.00	0.01/ 0.02	0.00	0.00	0.01	0.15	0.00	17
Yellow perch	1(5)	AL	0.2	6.2	0.87	8.0	92.0	0.00		0.37	56.8		24.3		18.9		0.35	0.01		0.05/ 0.01	0.01/ 0.05	0.01	0.00	0.01	1.50	0.00	17
Channel catfish	(28)	MH-4	1.01	11.2	3.08					1.53							0.06									ND	9
Alewife	1(6)	HB			0.45		76.0		24.0																		21
Spottail shiner	1(6)	HB			0.61		88.0		12.0																		21
Emerald shiner	1(6)	HB			0.04		65.0		35.0																		21
Carp	1(6)	HB			4.42		72.0		28.0																		21
Smelt	12(60)	O			0.19					0.07							0.01										22
Round whitefish	12	SB			0.44	23.2	49.0	27.2		0.07							0.01			0.01/ 0.00						0.00	23

(continued)

Table 5-1. (Concluded).

					P C B					D D T																
	# analysis # of fish	Location	mean weight(kg)	mean % lipids	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	dieldrin	hepta-chlor	hepta-chlor epoxide	chlordane cis/trans	nonachlor cis/trans	oxy-chlordane	HCB	alpha BHC	toxaphene	Hg	Source
1980																											
Coho salmon	(3)	TR	4.05		1.95	16.4	65.6	18.0	ND	0.41	89.3		6.6		4.3		0.04	ND	ND	0.03/ 0.01	0.02/ 0.05	0.01	T	0.01	1.5	0.23	24
Coho salmon	(10)	TR	3.08	6.6	2.28					0.40	100.0						0.02	T	T						T	0.22	9
Coho salmon	(1)	0			3.00																					0.37	6
Chinook salmon	(10)	TR	6.41	2.3	3.04		100.0			0.75	100.0						0.02	T	T						T	0.37	9
Chinook salmon	(1)	0			2.70					0.52																0.23	6
Lake trout	(25)	MH-4	2.47	12.1	3.16					0.77							0.12	T					T		ND	0.15	9
Brown trout	(1)	0			1.95																						6
Channel catfish	(18)	MH-4	2.14	13.7	6.80					1.00	100.0						0.02	ND					ND		ND	0.27	9
Carp	(15)	MH-4	5.04	11.1	9.47					0.79	100.0						0.01	ND					ND		ND	0.10	9
Lake trout	(47)	0			0.91					0.49							0.07										22
Smelt	24(120)	0			0.12					0.07							0.01										22
Walleye	(50)	0			0.19					0.17							0.02										22

Legend for Table 5-1.

1. Reinert. (1970). Whole fish.
2. Henderson et al. (1969). Whole fish.
3. Frank et al. (1978). Headless, gutted fish. Chlordane reported as sum of cis-, trans-isomers, and oxychlordane.
4. Henderson et al. (1971). Whole fish.
5. Henderson et al. (1972). Whole fish.
6. Clark. (1981). Whole fish and fish fillets.
7. Reinke et al. (1972). Headless, gutted fish. LOD: PCBs, DDT-R 1.0 µg.
8 Schmitt et al. (1981). Whole fish.
9. Forney. (1982). Skin-on and skinless fish fillets.
10. Environment Canada. (1972-1977). In: 1981 Report on Great Lakes Water Quality. Skinless fish fillets.
11. Armstrong and Lutz. (1977). Whole fish. Chlordane reported as sum of cis- , trans-isomers.
12. Michigan Department of Agriculture. (1975). Skin-on and skinless fish fillets.
13. Michigan Water Resources Commission. (1975). Skinless fillets.
14. Ontario Ministry of the Environment. (1976). Fish fillets.
15. Zabik et al. (1978). Mechanically deboned and whole fish.
16. Michigan Department of Agriculture. (1976). Skinless fillets.
17. Schmitt et al. (1983). Whole fish.
18. DeVault and Willford. (1982). Whole fish.
19. Simmons et al. (1982). Fish fillets. LOD: PCB, DDT, dieldrin, aldrin 0.0003 mg/kg.
20. Gledhill. (1978).
21. Anderson et al. (1982). Whole fish.
22. Fisheries and Oceans Canada. (1977-1980). In: 1981 Report on Great Lakes Water Quality. Whole fish.
23. Rice. (1979). Skinless fillets.
24. Clark et al. (1982). Skin-on fillets.

SB = Saginaw Bay
O = offshore
GB = Georgian Bay
NC = North Channel
MH1-5 = Michigan Statistical Fish Districts for Lake Huron (see segmentation scheme in Fig. 5-1).
AL = Alpena, Michigan
DI = Duck Island
LI = Lonely Island, Georgian Bay
MI = Mackinac Island
GH = Goderich, Ontario
HB = Harbor Beach, Michigan
TR = Tawas River, Tawas City, Michigan (Saginaw Bay)

ND = not detectable
T = trace
blank = no data
LOD = limit of detection

Table 5-2. Scientific and common names of Lake Huron fish. (after Robbins *et al*. 1980).

Scientific Name	Common Name
CLASS AGNATHA	
Order Petromyzontiformes	
Petromyzontidae	
Petromyzon marinus Linneaus	sea lamprey
CLASS OSTEICHTHYES	
Order Clupeiformes	
Clupeidae	
Alosa pseudoharengus (Wilson)	alewife
Order Salmoniformes	
Salmonidae	
Coregonus artedii Lesueur	cisco or lake herring
Coregonus clupeaformis (Mitchill)	lake whitefish
Coregonus hoyi (Gill)	bloater
Oncorhynchus kisutch (Walbaum)	coho salmon
Oncorhynchus nerka (Walbaum)	sockeye or kokanee salmon
Oncorhynchus tshawytscha (Walbaum)	chinook salmon
Prosopium cylindraceum (Pallas)	round whitefish
Salmo gairdneri Richardson	rainbow trout
Salmo trutta Linnaeus	brown trout
Salvelinus fontinalis X *S. namaycush*	splake
Salvelinus namaycush (Walbaum)	lake trout
Osmeridae	
Osmerus mordax (Mitchill)	rainbow smelt
Esocidae	
Esox lucius Linnaeus	northern pike

(Continued)

Table 5-2. (Concluded).

Scientific Name	Common Name
Order Cypriniformes	
Cyprinidae	
Cyprinus carpio Linnaeus	common carp
Notropis atherinoides Rafinesque	emerald shiner
Notropis hudsonius (Clinton)	spottail shiner
Catostomidae	
Catostomus commersoni (Lacepède)	white sucker
Order Siluriformes	
Ictaluridae	
Ictalurus punctatus (Rafinesque)	channel catfish
Order Gadiformes	
Gadidae	
Lota lota (Linnaeus)	burbot
Order Perciformes	
Centrarchidae	
Ambloplites rupestris (Rafinesque)	rock bass
Micropterus dolomieui Lacepède	smallmouth bass
Percidae	
Perca flavescens (Mitchill)	yellow perch
Stigostedion vitreum vitreum (Mitchill)	walleye
Cottidae	
Cottus cognatus Richardson	slimy sculpin

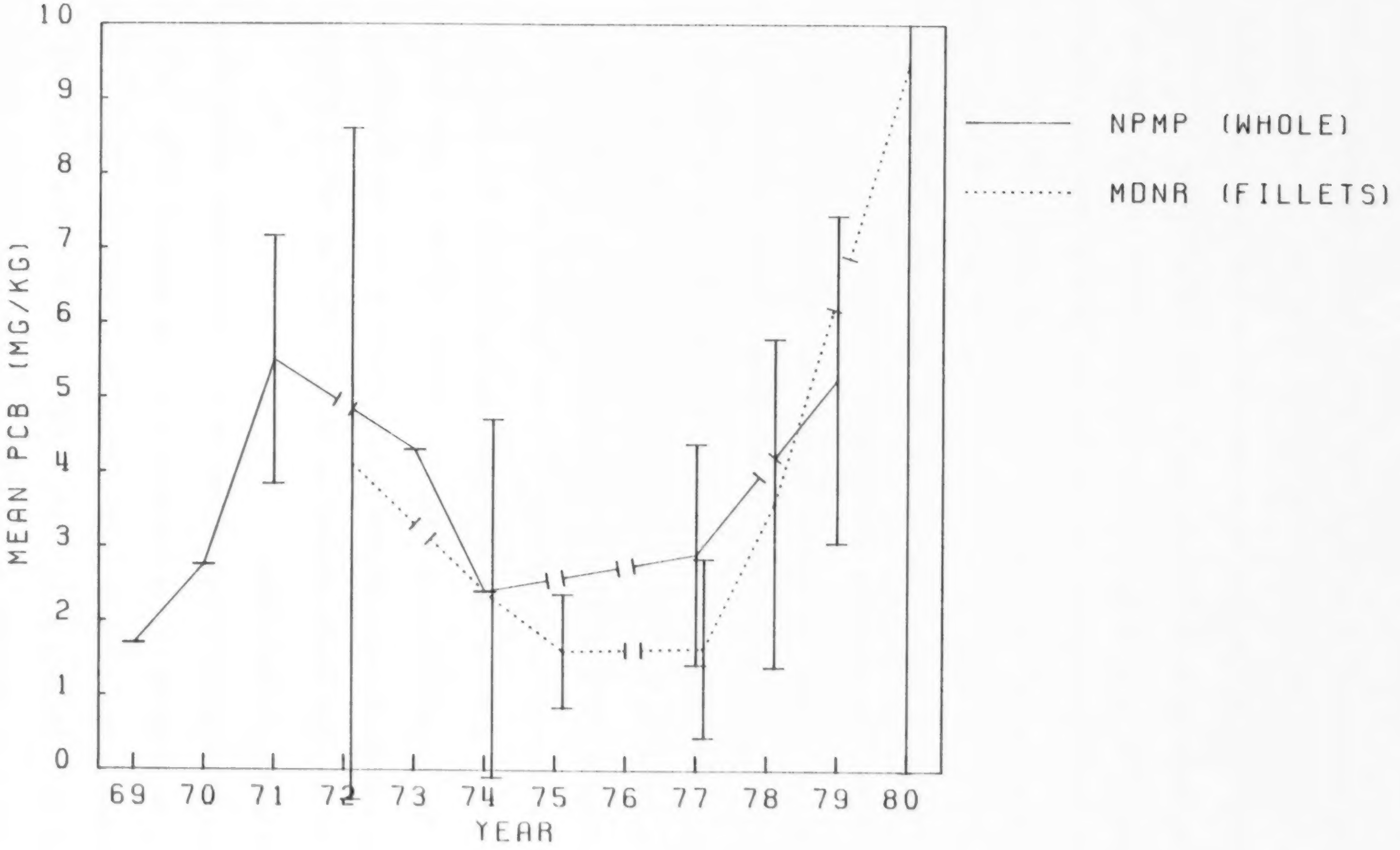

Figure 5-2. Yearly mean PCB concentrations (mg/kg) in Saginaw Bay common carp, 1969-1980. Error bars are ± one standard deviation.

decreasing concentrations through 1974-1975. Increasing mean concentrations were reported for 1977 through 1980 by both agencies. In 1975, fillets of common carp from the southern basin contained a mean PCB concentration of 1.22 mg/kg compared to a slightly higher mean concentration of 1.6 mg/kg in common carp fillets from Saginaw Bay in 1975 (Forney 1982). However, all yearly concentrations reported from Saginaw Bay were greater than the concentration reported from the southern basin in 1975 (Forney 1982). All reported PCB concentrations in common carp greatly exceed the IJC objective of 0.1 mg/kg. Forney (1982) also stated that 78% of the common carp collected in 1980 had PCB concentrations that exceeded 2.0 mg/kg.

Sampling periods for Saginaw Bay channel catfish by the NPMP and the MDNR were not concurrent (Fig. 5-3). Whole channel catfish exhibited the lowest yearly mean PCB concentration of 1.54 mg/kg in 1971 and the highest yearly mean of 6.6 mg/kg in 1973. The highest recorded mean concentration for channel catfish fillets of 8.16 mg/kg was also recorded in 1973 (Forney 1982). Substantially lower mean concentrations in fillets were observed from 1977 through 1979. However, the 1980 mean concentration of 6.8 mg/kg was the second highest PCB concentration observed for channel catfish fillets (Forney 1982). All mean concentrations reported are in excess of the IJC objective of 0.1 mg/kg, and 89% of the channel catfish in 1980 had concentrations greater than 2.0 mg/kg (Forney 1982).

Mean PCB concentrations in Saginaw Bay yellow perch showed large differences as recorded by the two main reporting agencies (Fig. 5-4). Mean concentrations in whole yellow perch fluctuated between 2.9 and 4.3 mg/kg between 1969 and 1977 (Schmitt et al. 1981, 1983). In 1979, the lowest mean for whole yellow perch was recorded by the NPMP at 0.67 mg/kg (Schmitt et al. 1983).

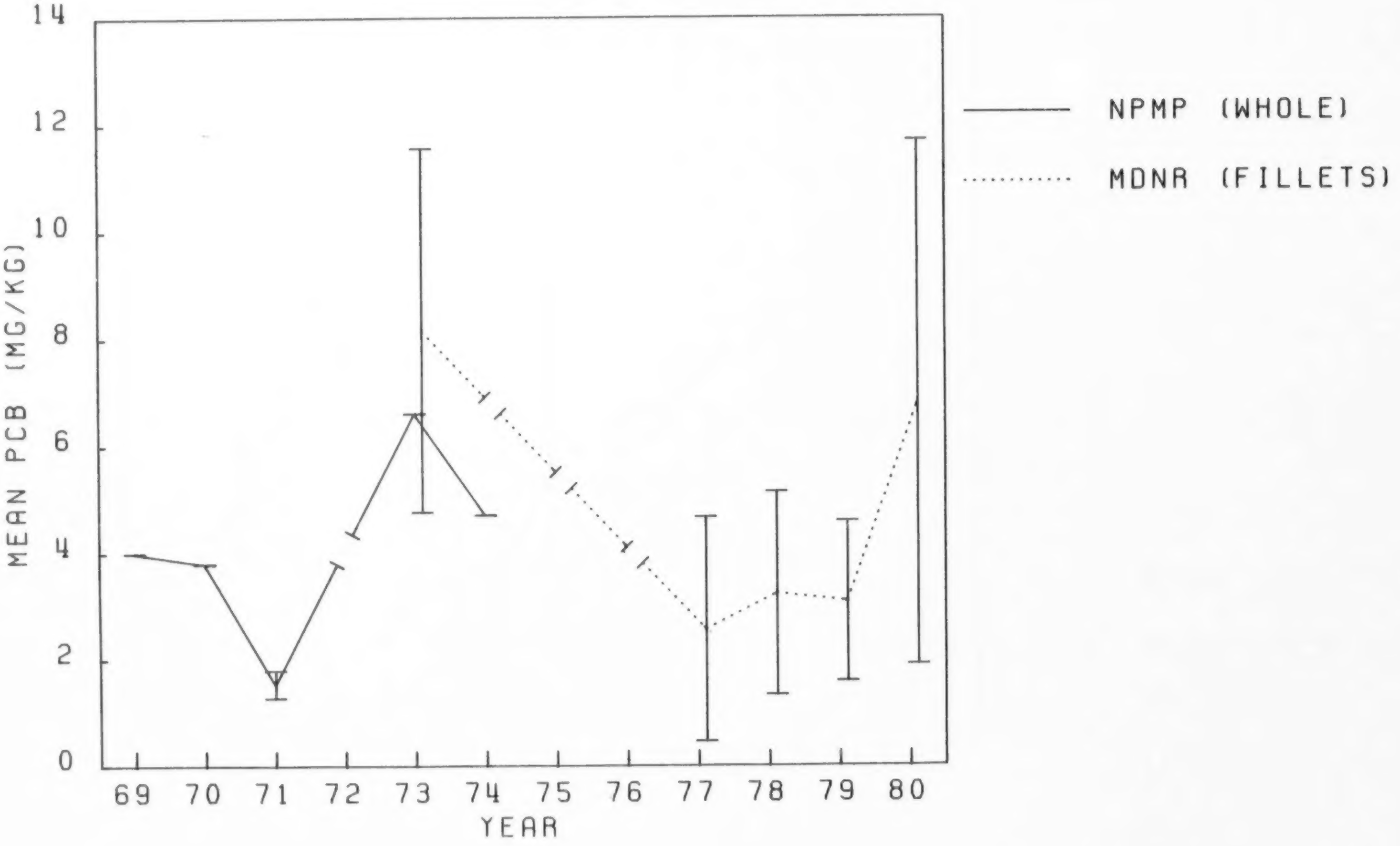

Figure 5-3. Yearly mean PCB concentrations (mg/kg) in Saginaw Bay channel catfish, 1969-1980. Error bars are ± one standard deviation.

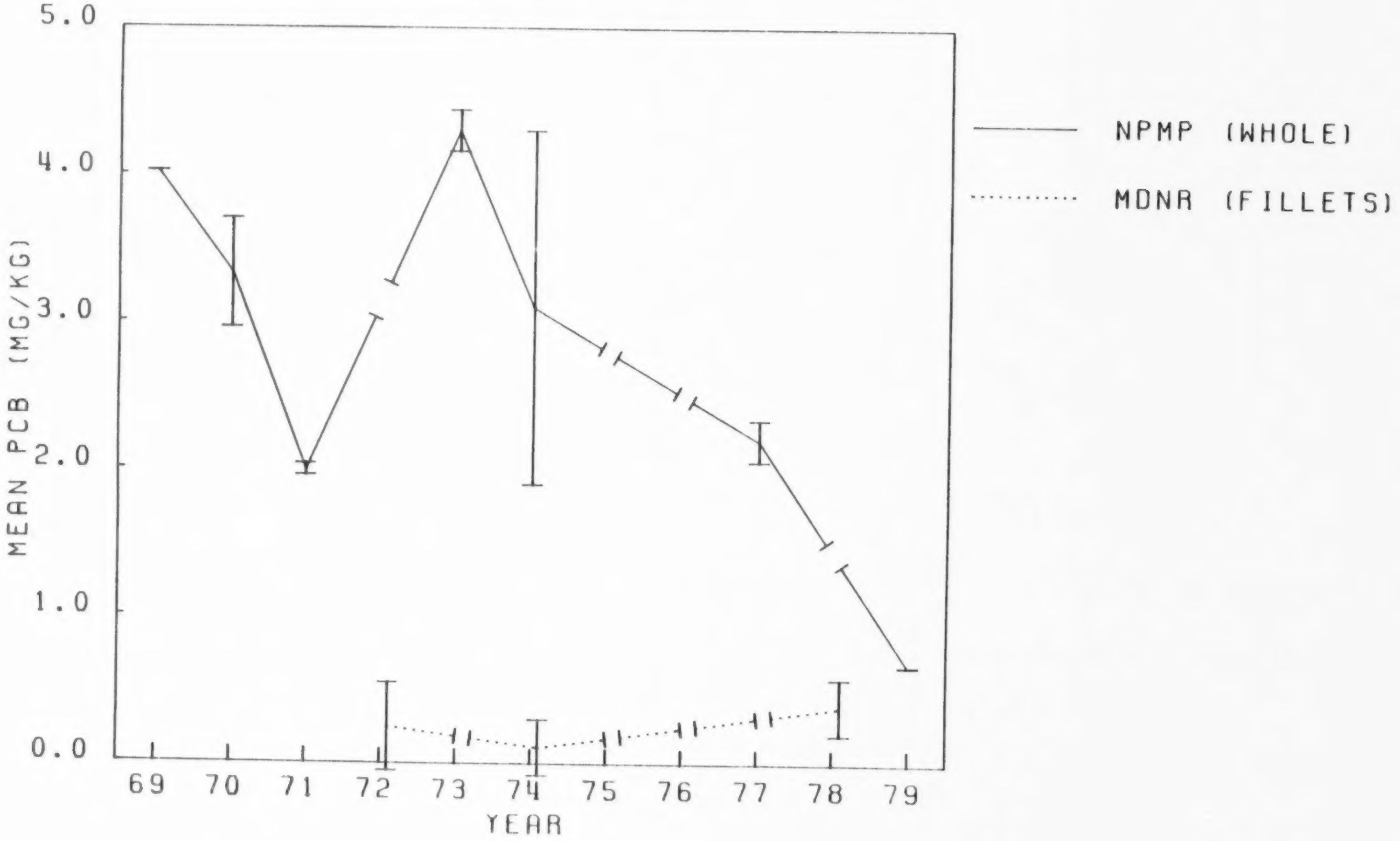

Figure 5-4. Yearly mean PCB concentrations (mg/kg) in Saginaw Bay yellow perch, 1969-1979. Error bars are ± one standard deviation.

Comparatively much lower concentrations were reported for skin-on perch fillets (Forney 1982). From limited data, low concentrations were reported in 1972 and 1974 with the highest mean concentration of 0.39 mg/kg reported in 1979 (Forney 1982). These results were the clearest example of differences which appear to result from the sample preparation methods utilized. From limited data, PCB concentrations in yellow perch collected from the main lake ranged from 0.01-0.69 mg/kg (Frank et al. 1978, Schmitt et al. 1983). PCB concentrations in all yellow perch collected from 1975 to 1979 exceed the IJC objective concentration of 0.1 mg/kg. Of those which were less than the IJC objective concentration prior to 1975, all were captured from areas other than Saginaw Bay.

A comparison of mean PCB concentrations in Saginaw Bay common carp, channel catfish, and yellow perch from compatible data on fillets is presented (Fig. 5-5). The data show that the edible portion of yellow perch contained considerably less PCB than did fillets of common carp or channel catfish. Channel catfish fillets contained slightly greater concentrations of PCB than did common carp in 1977, whereas common carp exhibited higher PCB concentrations in 1978 and 1980.

Most available data for PCB contamination in lake trout are for the period 1975 through 1980 (Table 5-1), with the bulk of data being reported for whole fish analyses from Alpena, Michigan, and fillet analyses from Saginaw Bay and the northern basin. The lowest mean PCB concentration of 0.7 mg/kg was recorded for whole lake trout in 1969 (Frank et al. 1978); other relatively low concentrations were 0.81 mg/kg for lake trout fillets in 1978 (Forney 1982) and 0.91 mg/kg for whole lake trout in 1980 (Fisheries and Oceans Canada 1977-1980). These concentrations were reported for fish collected in Georgian Bay, the northern basin, and open Lake Huron, respectively. The highest PCB concentration

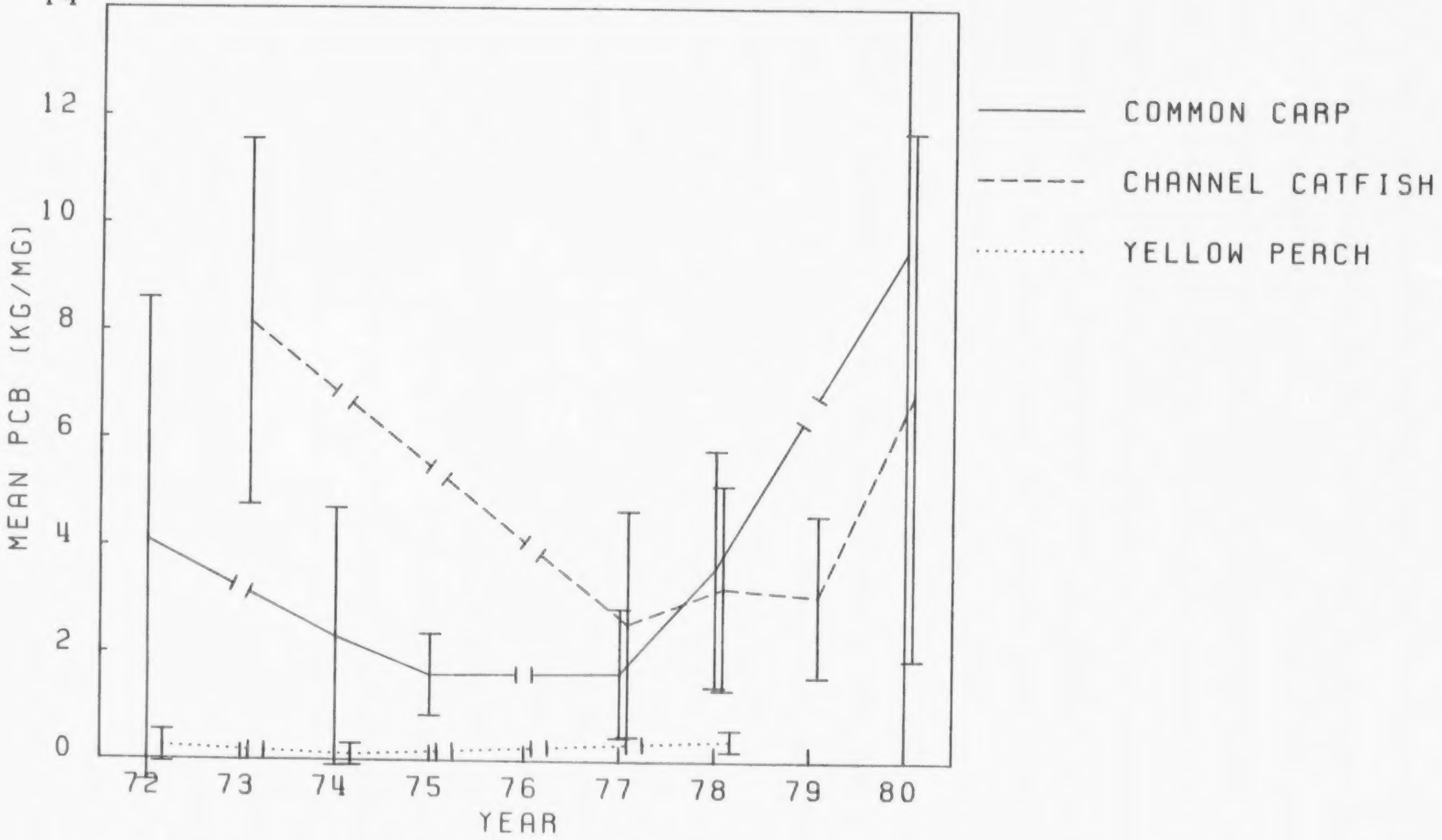

Figure 5-5. Comparison of yearly mean PCB concentrations (mg/kg) in Saginaw Bay common carp, channel catfish, and yellow perch fillets, 1972-1980. Error bars are ± one standard deviation.

of 6.46 mg/kg was reported for an individual whole lake trout collected at Alpena, Michigan, in 1979 (DeVault and Willford 1982). The highest PCB concentration detected in lake trout fillets was reported in 1975 at 5.70 mg/kg from the mid-southern basin (Forney 1982).

The most recent reports of PCB concentrations in Lake Huron lake trout were from surveys conducted in 1980 (Table 5-1). Whole lake trout from the offshore zone exhibited a relatively low PCB concentration of 0.91 mg/kg (Fisheries and Oceans Canada 1977-1980). Lake trout fillets from Saginaw Bay in 1980 contained the highest mean PCB concentration of 3.16 mg/kg that was ever reported from Saginaw Bay (Forney 1982). Also in 1980, 28% of all Saginaw Bay lake trout fillets had PCB concentrations exceeding 2.0 mg/kg (Forney 1982). However, all PCB concentrations reported for Lake Huron lake trout exceed the IJC objective of 0.1 mg/kg.

In general, higher PCB concentrations were usually observed in whole fish captured at Alpena, Michigan, than in fillet analyses of lake trout collected in the northern basin (Table 5-1). Similarly, lake trout collected in Saginaw Bay and the southern basin had higher mean PCB concentrations than lake trout from other areas (Table 5-1). A comparison of lake trout fillets from Saginaw Bay and the northern basin show that Saginaw Bay fillets had higher mean PCB concentrations than those from the northern basin (Fig. 5-6).

PCB concentrations for three lake trout size classes collected over three consecutive years at Alpena, Michigan, are presented in Figure 5-7. These data indicate biomagnification with mean concentrations increasing for each successively greater weight class (DeVault and Willford 1982). Of particular interest is the increase in mean PCB concentrations in the same size class for successive years. These data indicate increases in PCBs in lake trout at this site.

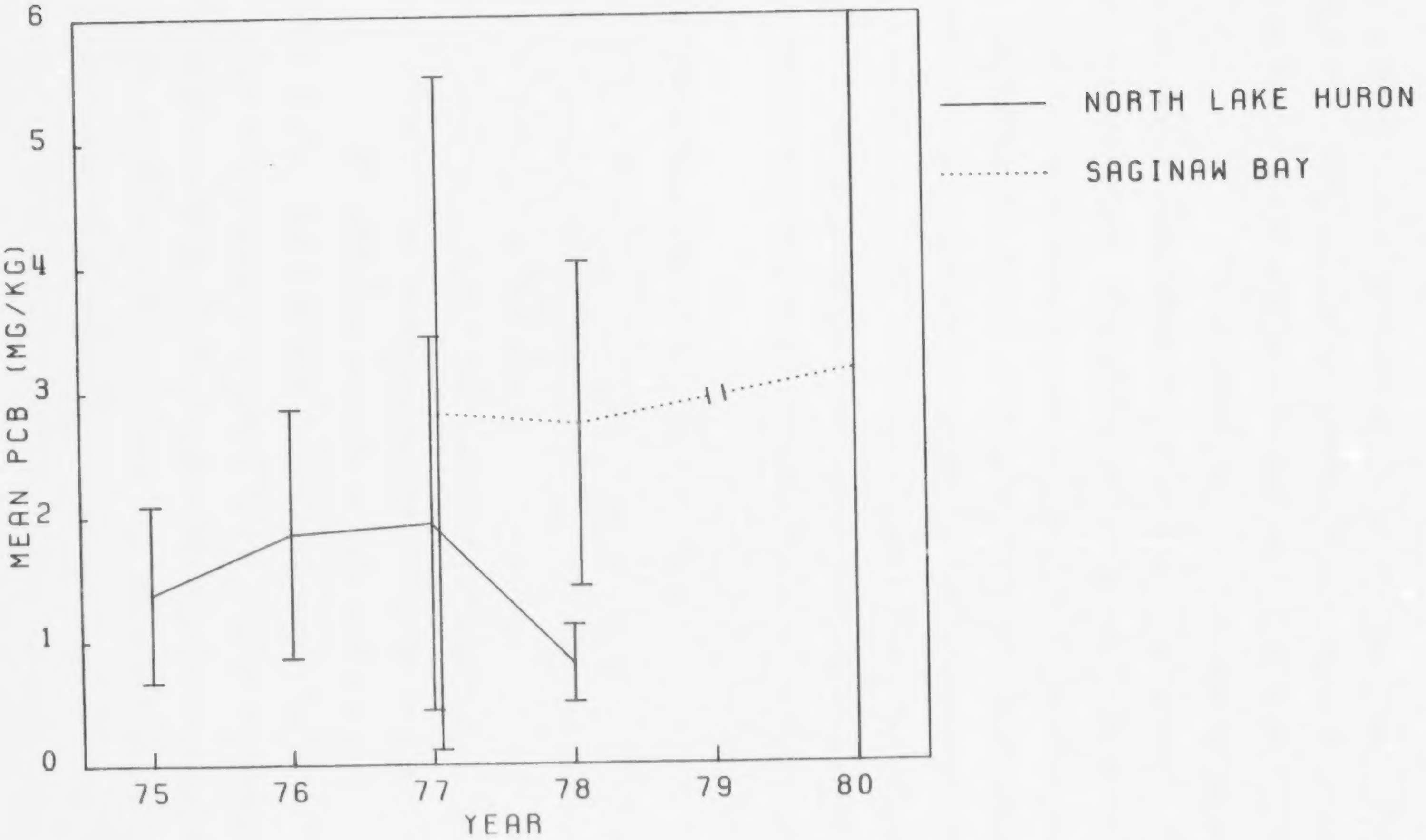

Figure 5-6. Comparison of yearly mean PCB concentrations (mg/kg) in Northern Lake Huron and Saginaw Bay lake trout fillets, 1975-1980. Error bars are ± one standard deviation.

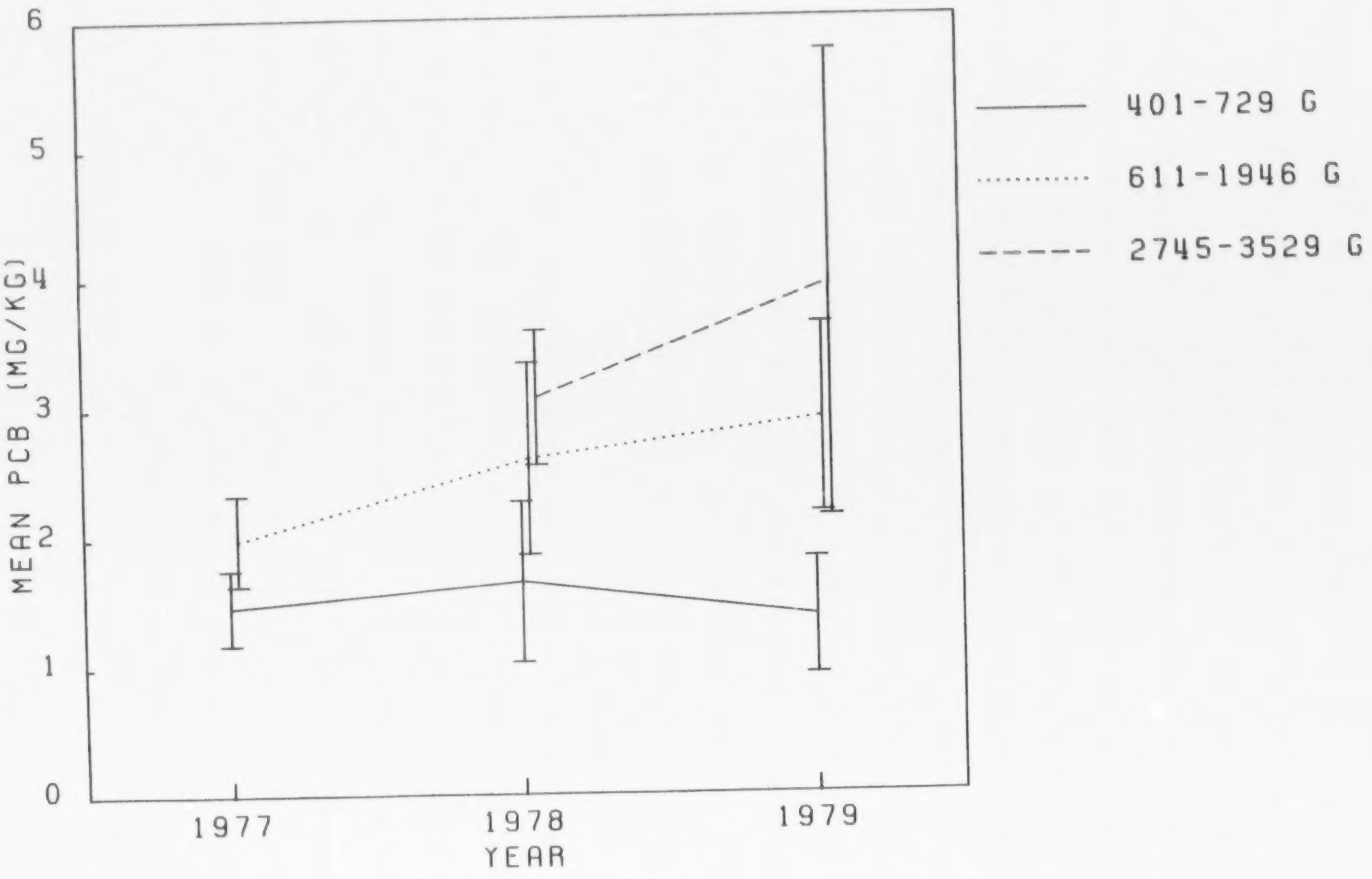

Figure 5-7. Comparison of yearly mean PCB concentrations (mg/kg) in three Lake Huron lake trout size classes from Alpena, Michigan, 1977-1979. Analyses performed on whole fish. Error bars are ± one standard deviation.

However, the smallest size class in 1979 had lower concentrations than the two preceding years. This may indicate a decrease in PCBs in subsequent lake trout classes at this locality and suggests further monitoring is necessary to determine whether or not these trends continue.

Yearly mean PCB concentrations in headless, gutted lake whitefish are relatively low and uniform (Fig. 5-8). Yearly mean concentrations were less than 0.2 mg/kg between 1969 and 1976 with individual concentrations ranging from 0.04 to 0.6 mg/kg (Fig. 5-8 and Table 5-1, respectively). However, the highest mean PCB concentration reported for lake whitefish (0.64 mg/kg) was for fillets collected near Saginaw Bay in 1972 (Forney 1982). Regional differences in PCB concentrations were not distinct for lake whitefish; all regions exhibit a modest range in concentrations. The most recent analyses of lake whitefish in 1976 show PCB concentrations in headless, gutted fish ranging from 0.1 to 0.2 mg/kg. All mean PCB concentrations in lake whitefish exceed the IJC objective of 0.1 mg/kg.

The longest available time series trend for coho salmon are for headless, gutted fish and show slightly increasing PCB concentrations between 1968 and 1975 (Fig. 5-9). The highest yearly mean PCB concentration was observed in 1975 at 1.3 mg/kg (Fig. 5-9). The highest individual PCB concentration in coho salmon was reported in 1972 at 5.4 mg/kg (Environment Canada 1972-1977). The most recent analyses of coho salmon in 1980 showed PCB concentrations ranging from 1.95 to 3.00 mg/kg (Table 5-1). All PCB concentrations in coho salmon are above the IJC objective of 0.1 mg/kg.

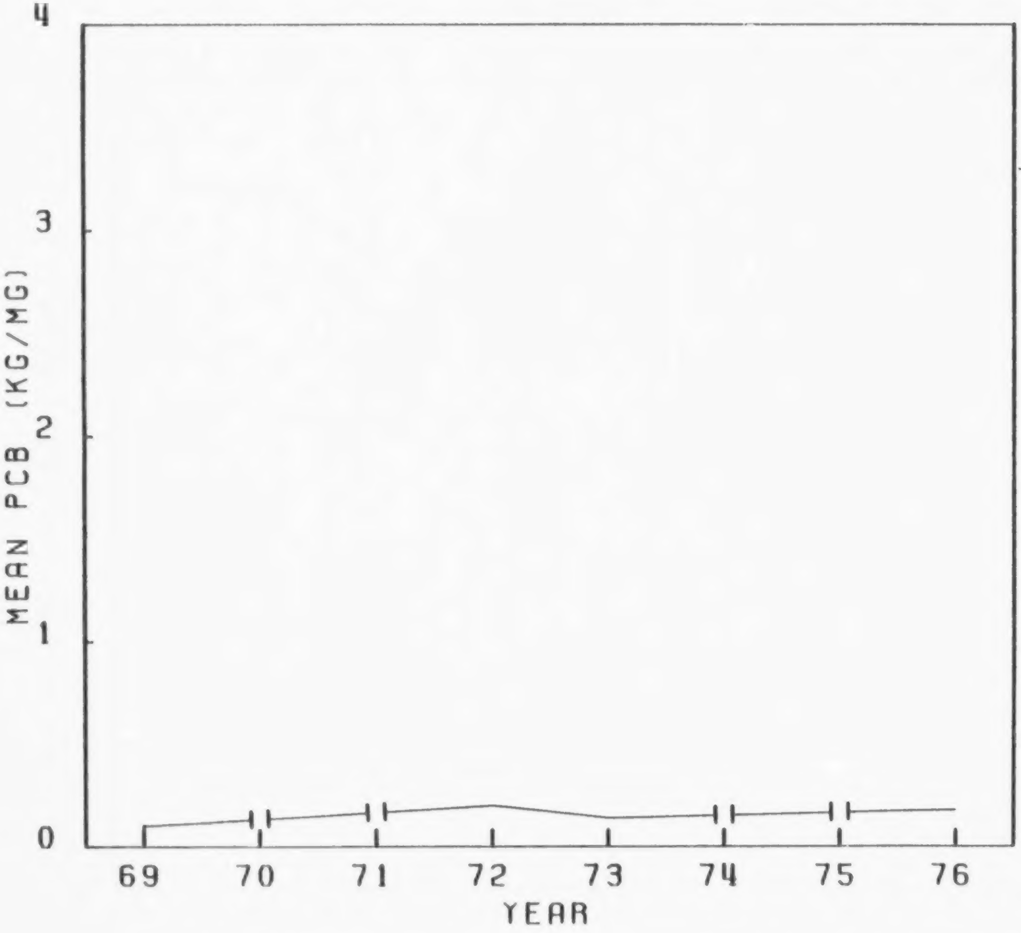

Figure 5-8. Yearly mean PCB concentrations (mg/kg) in offshore Lake Huron lake whitefish, 1969-1976. Analyses conducted on headless, gutted fish.

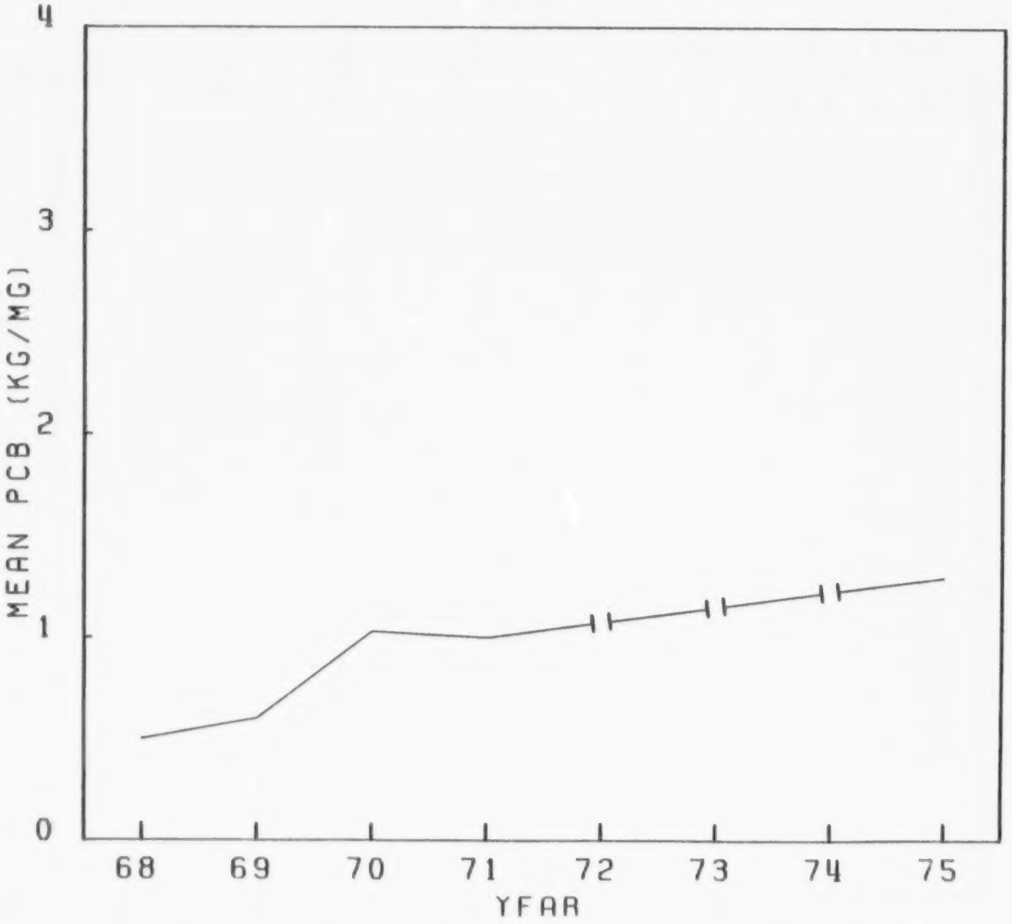

Figure 5-9. Yearly mean PCB concentrations (mg/kg) in offshore Lake Huron coho salmon, 1968-1975. Analyses of headless, gutted fish.

Data for the remainder of fish species discussed below were sparse, collected from numerous sites, and were not analyzed using comparable methods. These data are discussed below but were not suitable for plotting.

Chinook salmon fillets showed a high mean PCB concentration of 9.2 mg/kg in 1973 (Forney 1982). Lower concentrations have been recorded since that time, with concentrations of 3.04 and 2.70 mg/kg being recorded for 1980 (Forney 1982, Clark 1981). All concentrations are above the IJC objective of 0.1 mg/kg.

The highest mean PCB concentration detected in bloater was 5.2 mg/kg in 1971 (Table 5-1). This concentration was reported for headless, gutted bloater captured in Georgian Bay (Frank et al. 1978). The lowest PCB concentration reported for bloater was 0.2 mg/kg in 1969 for headless, gutted fish collected in offshore waters (Table 5-1). The most recent data for PCB concentrations in bloater are from collections in 1978, where bloater fillets from Saginaw Bay contained 0.41 mg/kg (Table 5-1). During 1974, the most extensive survey for PCB contamination in bloater was conducted (Armstrong and Lutz 1977). On the basis of whole fish analyses, PCBs were higher in bloater captured at Alpena, Michigan, than from Georgian Bay and the northern and southern basins. Georgian Bay bloater contained the lowest PCB concentration at 0.89 mg/kg. All mean PCB concentrations reported for bloater are in excess of the IJC objective of 0.1 mg/kg.

Brown trout data are available from 1973 to 1980. In 1973, the highest mean PCB concentration of 3.59 mg/kg was reported in fillets (Forney 1982). During 1974 and 1975, individual mean concentrations ranged from 0.26 to 1.93 mg/kg (Table 5-1). In 1980, brown trout contained a PCB concentration of 1.95 mg/kg (Clark 1981). All concentrations are above the IJC objective of 0.1 mg/kg.

Other species sporadically exhibited high mean PCB concentrations at one time or another. Examples are splake (6.0 mg/kg) in 1975, rainbow trout (2.06 mg/kg) in 1974, cisco (2.2 mg/kg) in 1975, and burbot (2.35 mg/kg) in 1974 (Table 5-1).

In general, most of the smaller fish species, i.e., smelt, shiners, alewives, slimy sculpin, and smallmouth bass, had relatively low PCB concentrations (Table 5-1). Since 1977, no mean concentrations reported are lower than the IJC objective including those for smaller fish. Typically, collections prior to 1977 contained smaller fish usually having PCB concentrations at or below the IJC objective level.

Comparing PCB concentrations in fish species captured from the main lake (Fig. 5-10), lake trout showed considerably higher mean concentrations than walleye and lake whitefish, although collection dates were not all concurrent. Concentrations are reported for fish fillets captured in northern Lake Huron. Walleye showed higher mean concentrations than lake whitefish in 1973, but comparable values were observed in 1975. During 1975 and 1978, lake trout exhibited higher mean concentrations than whitefish and walleye, respectively.

A source of data variance was detected in the MDNR values reported for PCBs (Forney 1982). All PCB reports are for Aroclor 1254 only. Available data from 1980 for common carp and channel catfish indicate that total PCB concentrations are approximately twice the amount reported when concentrations of Aroclor 1242 are included. This would indicate that the portion of Aroclor 1242 is, on average, approximately equal to that of 1254. The analytical results of Aroclor 1242 were not reported for consistency with earlier data, because it was not sought in earlier analyses and confidence in the later analyses was not exhibited (Forney, J., personal communication).

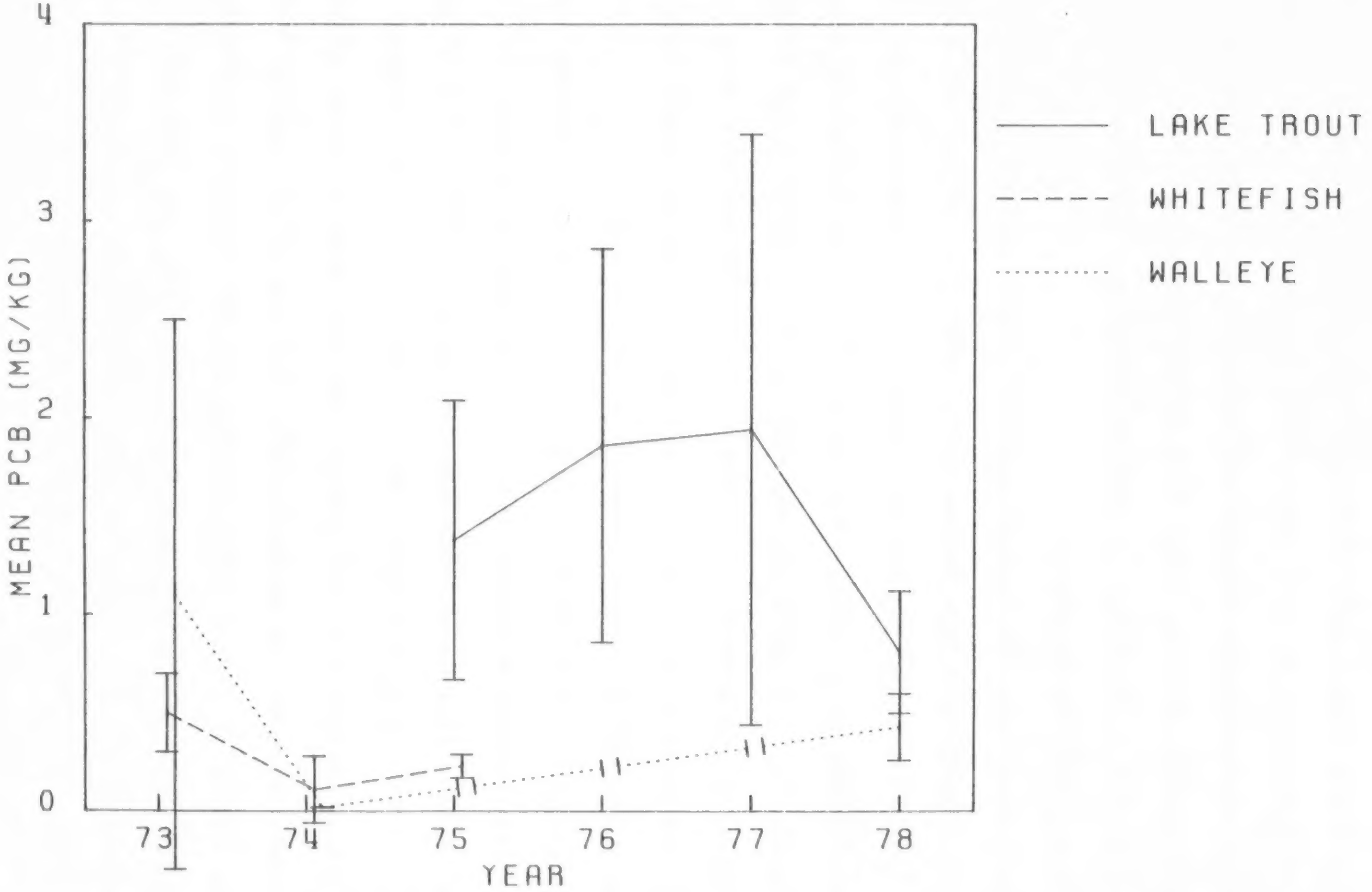

Figure 5-10. Comparison of yearly mean PCB concentrations (mg/kg) in offshore Northern Lake Huron lake trout, lake whitefish, and walleye fillets, 1973-1978. Error bars are ± one standard deviation.

DDT-R

The single highest mean DDT-R concentration of 10.15 mg/kg was reported for coho salmon from the main lake in 1970 (Reinke et al. 1972). Other high mean DDT-R concentrations observed were for coho salmon (8.15 mg/kg) from Georgian Bay in 1970, for lake trout (7.60 mg/kg) from Georgian Bay in 1969, and in channel catfish (6.90 mg/kg) in 1966 (Reinke et al. 1972, Frank et al. 1978, and Reinert 1970, respectively).

For common carp, the highest mean DDT-R concentration of 2.50 mg/kg was reported in whole fish from Saginaw Bay in 1967 (Fig. 5-11). All subsequent DDT-R concentrations in Saginaw Bay common carp were lower than the 1967 concentration (Schmitt et al. 1981, 1983; Forney 1982). The second highest mean concentration of 1.23 mg/kg was recorded in 1970 (Schmitt et al. 1983). The mean DDT-R concentration for common carp in 1980 was 0.79 mg/kg for Saginaw Bay fillets (Forney 1982). All reported DDT-R values for common carp since 1972 fall below the IJC objective concentration of 1.0 mg/kg.

The single highest DDT-R concentration in channel catfish was 6.90 mg/kg (Table 5-1) recorded by Reinert (1970). Other high DDT-R means recorded for channel catfish from Saginaw Bay were 3.35 mg/kg in 1968 by Schmitt et al. (1981) and 3.82 mg/kg by Forney (1982) in 1973 (Fig. 5-12). Compared to 1973, DDT-R concentrations from 1977 through 1980 were greatly reduced (Forney 1982) with a mean value of 1.00 mg/kg in 1980. The mean DDT-R concentration for channel catfish in 1979 slightly exceeded the IJC objective concentration of 1.0 mg/kg. However, concentrations from 1977, 1978, and 1980 were at or below the objective.

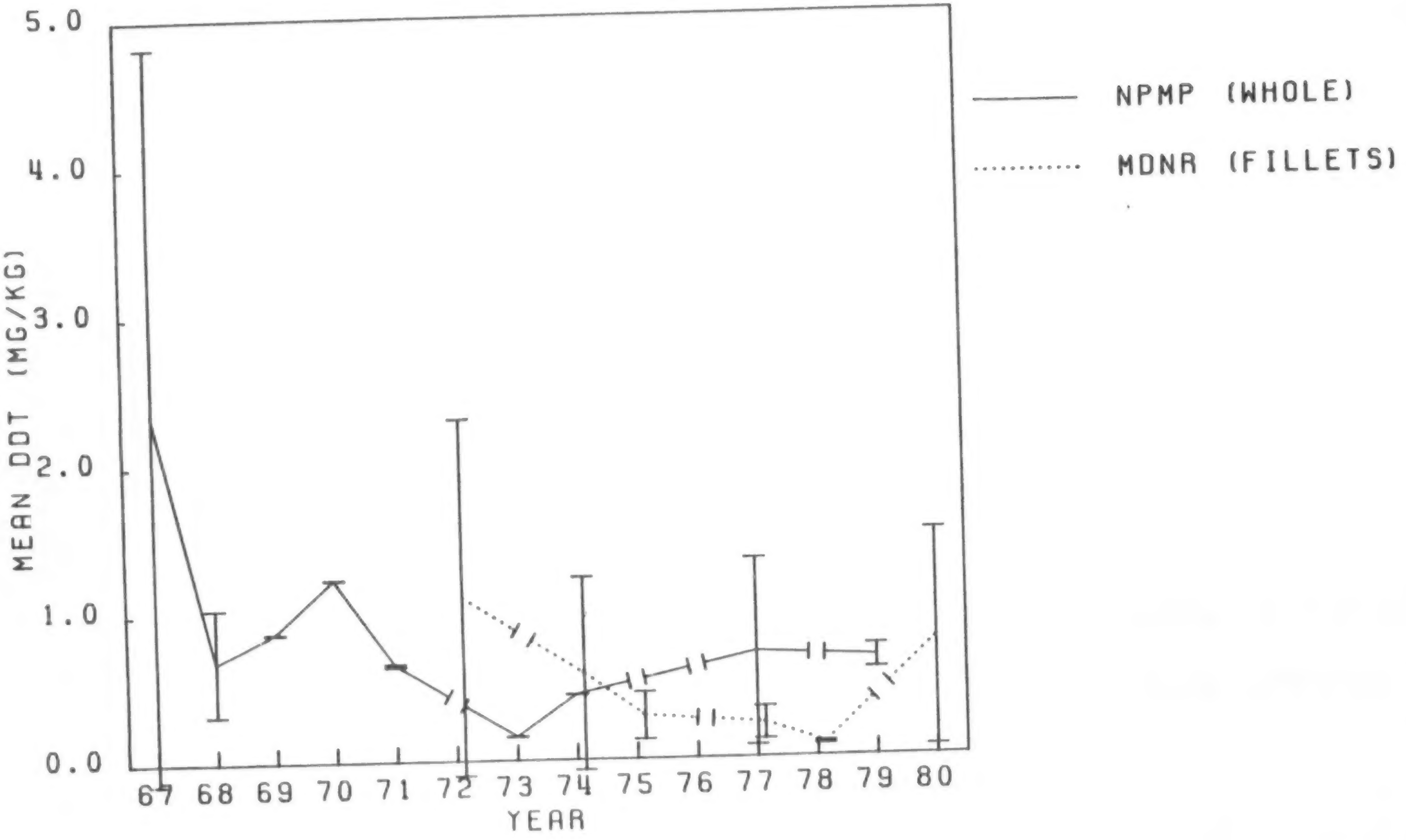

Figure 5-11. Yearly mean DDT-R concentrations (mg/kg) in Saginaw Bay common carp, 1967-1980. Error bars are ± one standard deviation.

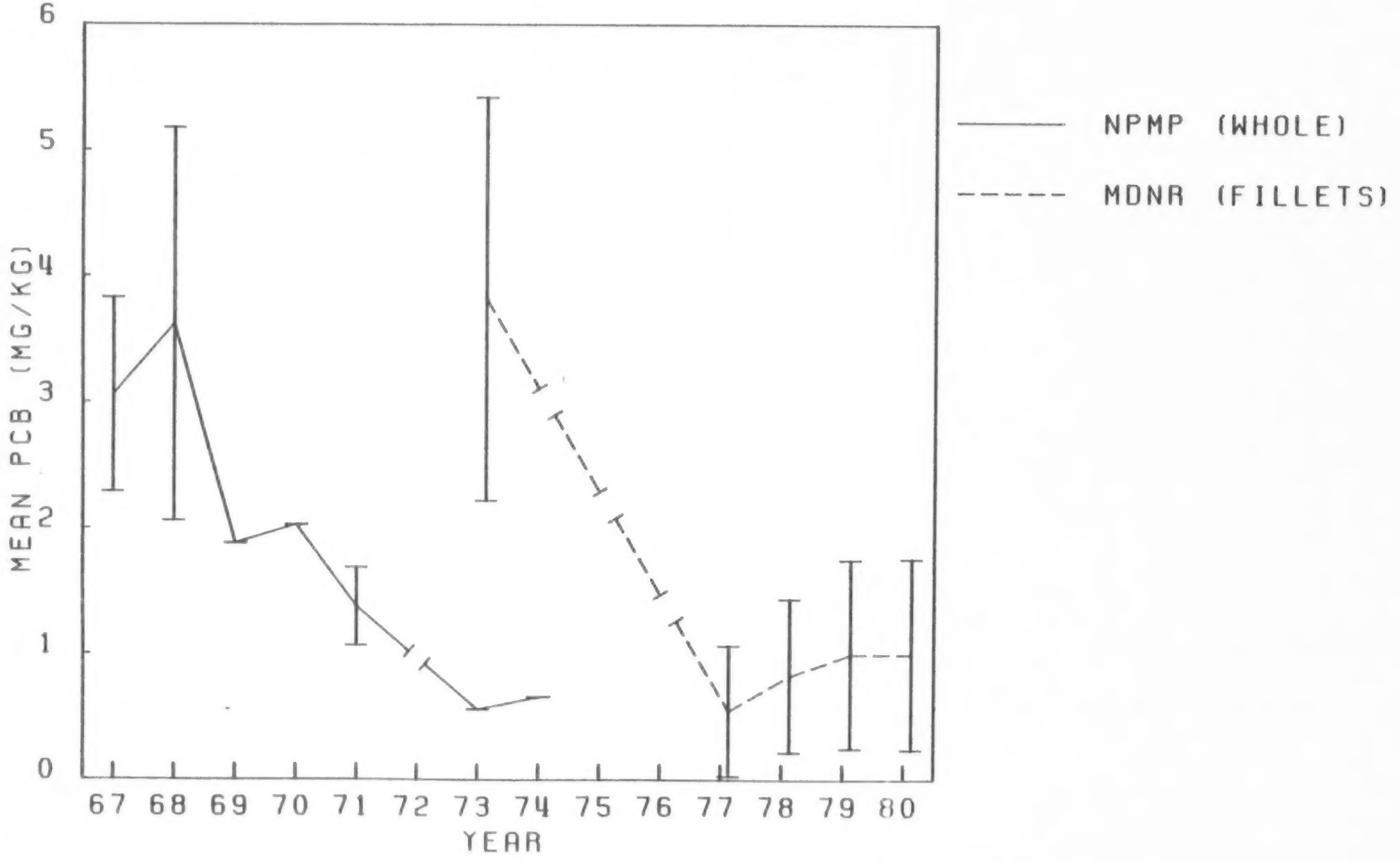

Figure 5-12. Yearly mean DDT-R concentrations (mg/kg) in Saginaw Bay channel catfish, 1967-1980. Error bars are ± one standard deviation.

DDT-R concentrations in Saginaw Bay perch were highest (1.66 mg/kg) in 1967 (Fig. 5-13). Lower concentrations have been reported through 1980. A distinct concentration difference was noted between the NPMP and the MDNR data sets (Fig. 5-13). Edible portions of yellow perch (Forney 1982) had much lower mean DDT concentrations than whole fish (Schmitt et al. 1981, 1983). Recent concentrations for 1979 are at 0.15 mg/kg (Schmitt et al. 1983). Main lake concentrations for yellow perch ranged between 0.01 and 0.32 mg/kg between 1968 and 1979. A high concentration of 1.46 mg/kg was reported in yellow perch from Georgian Bay in 1970 (Reinke et al. 1972). Since 1971, all DDT-R concentrations for yellow perch are below the IJC objective of 1.0 mg/kg.

The highest DDT-R concentration observed in lake trout was 7.60 mg/kg reported for Georgian Bay trout in 1969 (Frank et al. 1978). The highest mean concentration for Saginaw Bay lake trout was 2.82 mg/kg in 1977 (Forney 1982). Saginaw Bay lake trout showed concentrations similar to those captured in the main lake from 1978 through 1980 (Table 5-1). However, comparing data sets for Saginaw Bay and northern Lake Huron trout fillets (Forney 1982), higher mean concentrations were observed in Saginaw Bay lake trout during the same years (Fig. 5-14). The lowest mean DDT-R concentration for trout from the main lake (0.49 mg/kg) was recorded in 1980 (Fisheries and Oceans Canada 1977-80). Mean concentrations in 1980 for both open lake and Saginaw Bay captured trout were below the IJC objective of 1.0 mg/kg. All other yearly mean concentrations between 1975 and 1979 were above the IJC objective, although some individual samples between 1975 and 1979 were under the IJC objective concentration (Table 5-1).

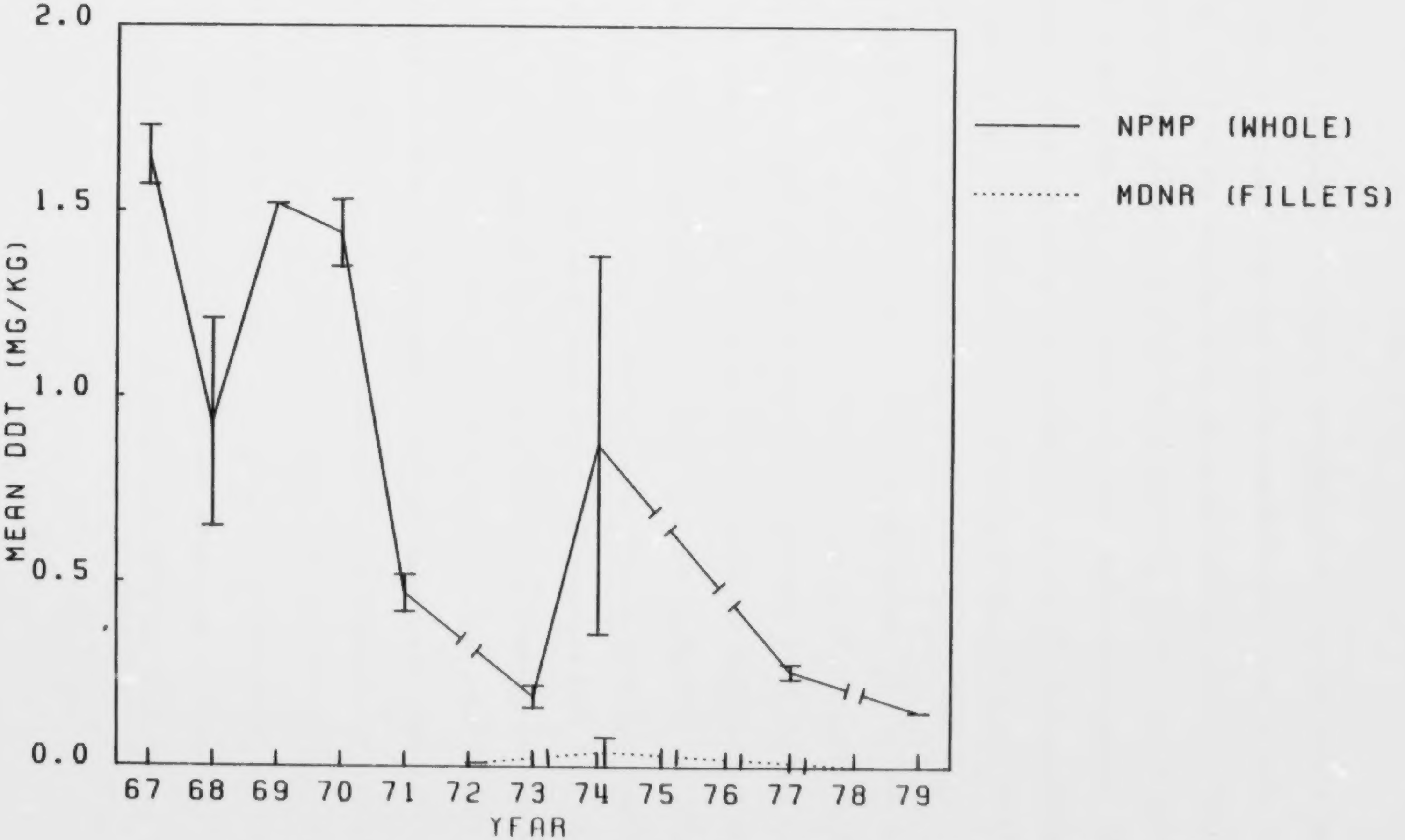

Figure 5-13. Yearly mean DDT-R concentrations (mg/kg) in Saginaw Bay yellow perch, 1967-1979. Error bars are ± one standard deviation.

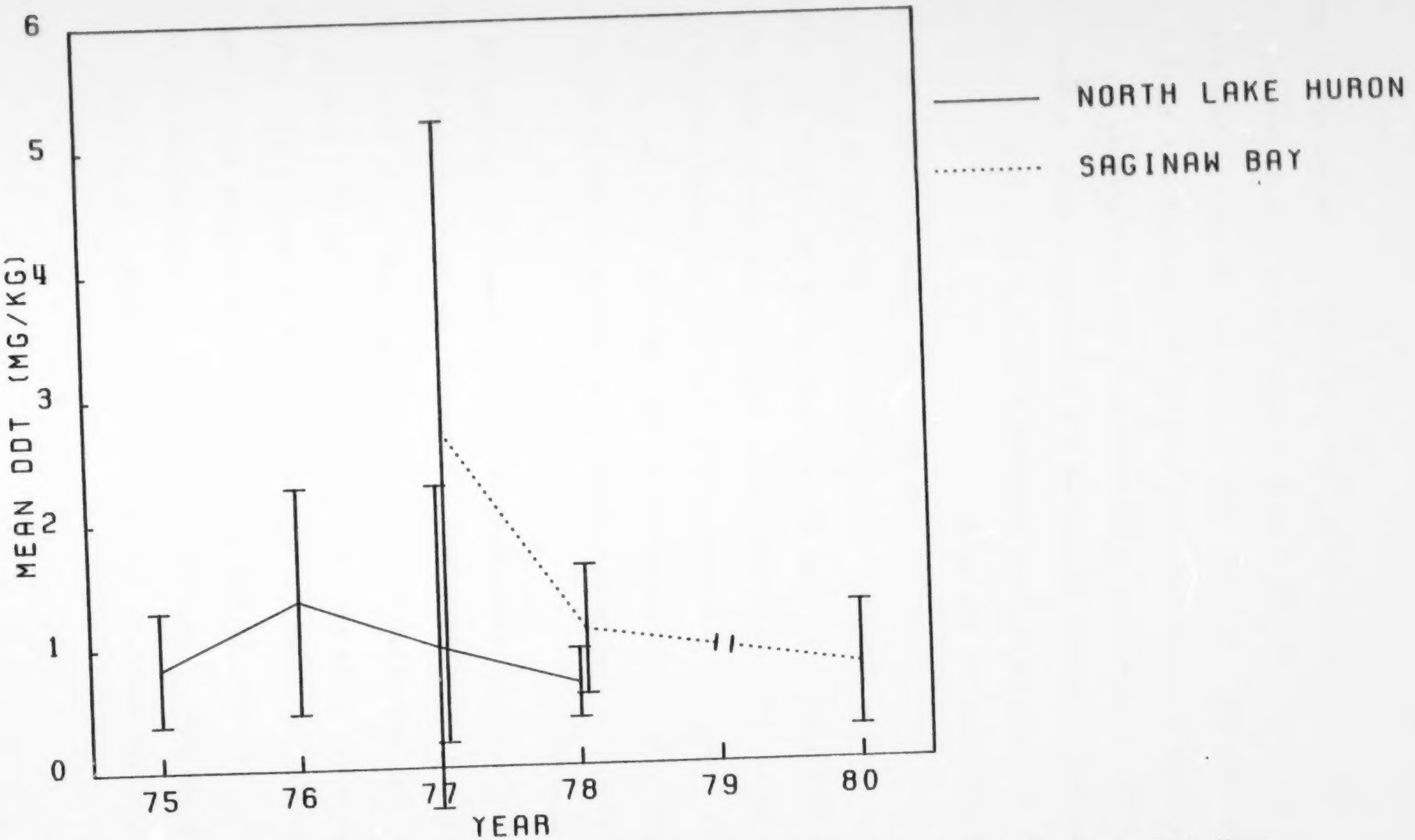

Figure 5-14. Comparison of yearly mean DDT-R concentrations (mg/kg) in Northern Lake Huron and Saginaw Bay lake trout fillets, 1975-1980. Error bars are ± one standard deviation.

DDT-R concentrations in fillets of three Saginaw Bay species are compared in Figure 5-15. For the data available, yellow perch fillets contained considerably less DDT-R than did those of carp and lake trout. Lake trout showed higher mean concentrations than carp in 1977 and 1978 with similar values for 1980. A comparison of DDT-R in whole fish from Saginaw Bay is given in Figure 5-16. Channel catfish had the highest mean concentrations. Both yellow perch and carp had similar concentrations until 1977, when carp had higher concentrations than did perch.

Available data for DDT residues in the following species were not adequate for time series plotting. Concentrations are discussed on a species-by-species basis from Table 5-1. Mean DDT-R concentrations in bloater were lowest in 1969 (0.61 mg/kg) and rose to the highest reported mean concentration of 5.18 mg/kg in 1971 (Table 5-1). Concentrations generally decreased since 1971; however, all individual mean concentrations since 1969 are above the IJC objective of 1.0 mg/kg. The most recent collection of bloater in 1978 showed a concentration of 1.06 mg/kg.

Lake whitefish concentrations of DDT-R showed its highest mean of 2.43 mg/kg in 1966 (Table 5-1). Concentrations decreased through 1976 when the lowest mean concentration reached 0.12 mg/kg (Frank et al. 1978). All mean concentrations since 1970 are below the IJC objective of 1.0 mg/kg.

Walleye exhibited its highest mean DDT-R concentration of 6.02 mg/kg in 1966 with subsequently decreasing concentrations to lows of 0.16 and 0.17 mg/kg in 1974 and 1980, respectively (Table 5-1). All mean concentrations for walleye since 1972 are below the IJC objective concentration of 1.0 mg/kg.

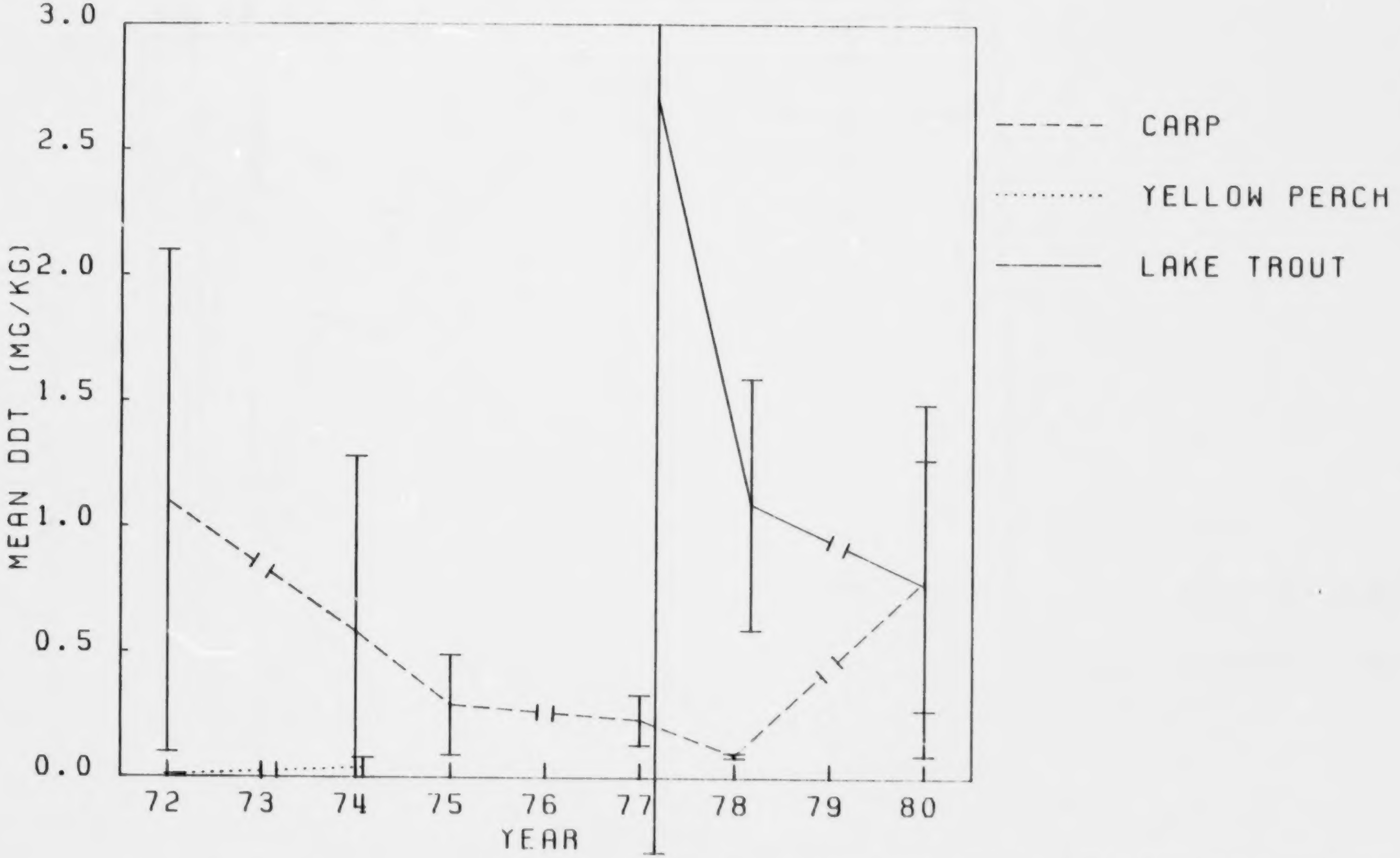

Figure 5-15. Comparison of yearly mean DDT-R concentrations (mg/kg) in Saginaw Bay common carp, yellow perch, and lake trout fillets, 1972-1980. Error bars are ± one standard deviation.

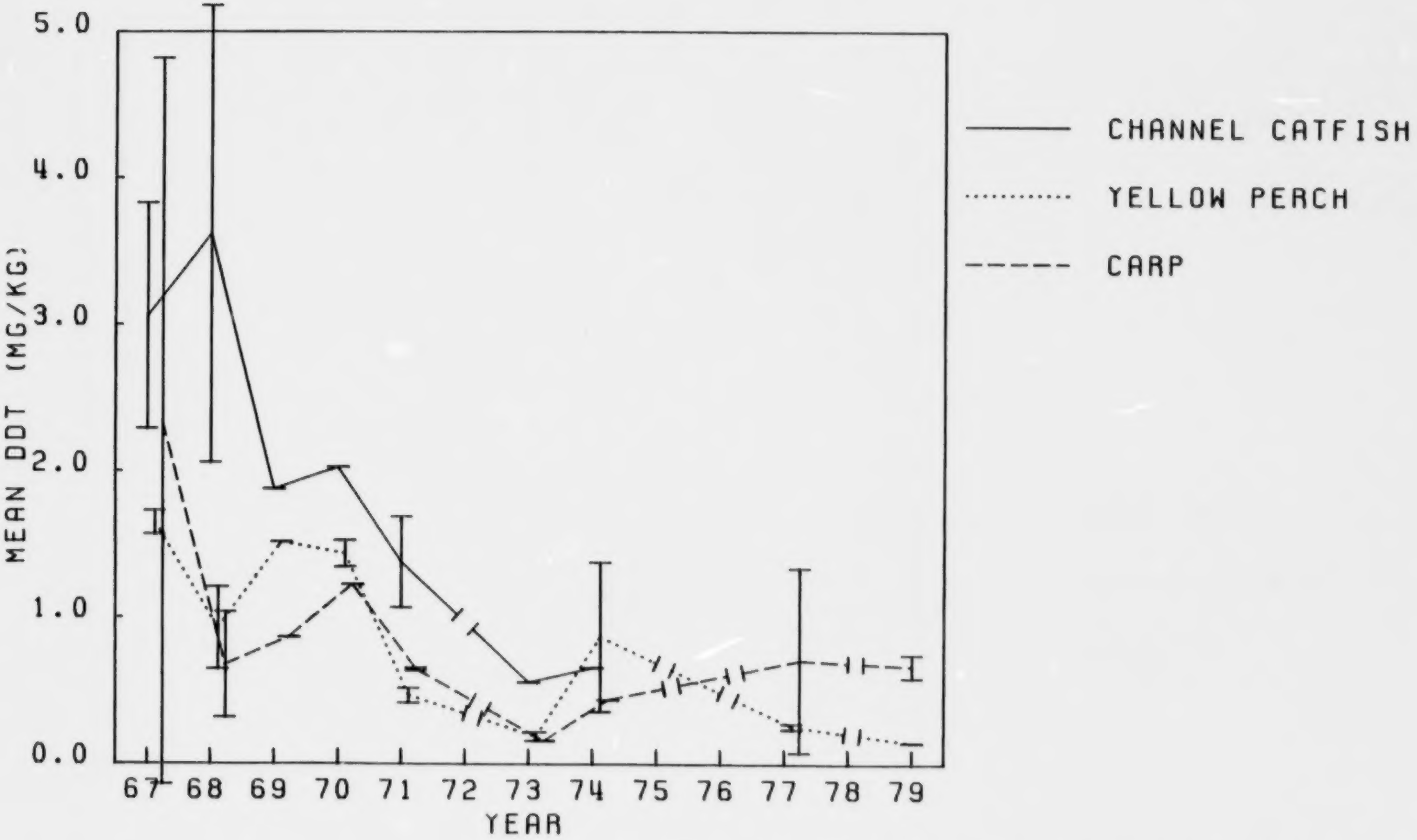

Figure 5-16. Comparison of yearly mean DDT-R concentrations in Saginaw Bay channel catfish, yellow perch, and common carp, 1967-1979. Analyses conducted on whole fish. Error bars are ± one standard deviation.

Coho salmon showed a high mean DDT-R concentration of 10.5 mg/kg in 1970 (Fig. 5-1). Concentrations have decreased through 1980 when the lowest mean of 0.40 mg/kg was recorded (Forney 1982). Concentrations for the most recent collection years in 1975 and 1980 are below the IJC objective of 1.0 mg/kg.

The highest mean DDT-R concentration for chinook salmon of 5.8 mg/kg was observed in 1973 (Forney 1982). DDT-R concentrations from 1975 and 1980 for chinook fall below the IJC objective of 1.0 mg/kg.

The highest mean DDT-R concentration recorded for brown trout was 2.21 mg/kg 1973 (Table 5-1). DDT-R concentrations for 1974 and 1975 fall under the IJC objective of 1.0 mg/kg.

Other high DDT-R concentrations observed were for splake (2.68 mg/kg) in 1975, Saginaw Bay mullet (2.99 mg/kg) in 1970, yellow pickerel (4.29 mg/kg) in 1970, and alewife (2.44 mg/kg) in 1966. Since then, most of these fish have had lower concentrations reported. All fish collected during 1980 had DDT-R concentrations at or below the IJC objective of 1.0 mg/kg.

Comparing DDT-R concentrations in main lake fish, lake trout showed higher mean concentrations than did walleye and lake whitefish (Fig. 5-17). When comparisons could be made, walleye and lake whitefish exhibited similar DDT-R concentrations.

Dieldrin and Aldrin

Most data for dieldrin were not suitable for plotting, and concentrations are discussed from Table 5-1. The highest individual mean concentration of dieldrin (0.50 mg/kg) was detected in lake trout from Alpena, Michigan in 1979 (Table 5-1). Other high concentrations observed were for splake (0.48 mg/kg) in 1975, bloater from Goderich, Ontario, (0.38 mg/kg) in 1974, yellow perch

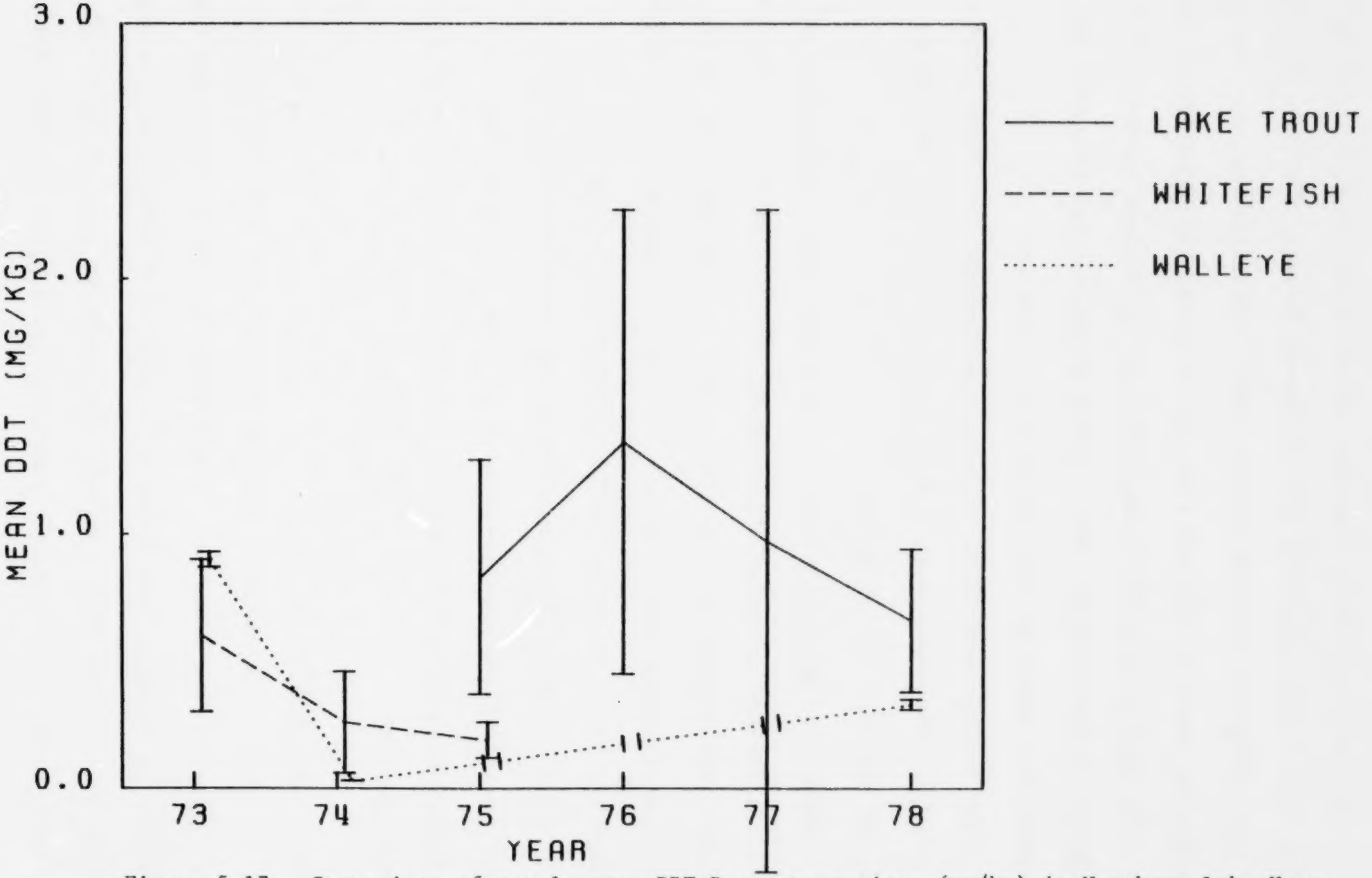

Figure 5-17. Comparison of yearly mean DDT-R concentrations (mg/kg) in Northern Lake Huron lake trout, lake whitefish, and walleye fillets, 1973-1978. Error bars are ± one standard deviation.

from Alpena, Michigan, (0.35 mg/kg) in 1980, and lake trout from Alpena, Michigan, (0.34 mg/kg) in 1977 (Table 5-1).

Dieldrin concentrations in Saginaw Bay carp ranged from 0.00 mg/kg in 1973 and 1974 to 0.05 mg/kg in 1972 (Table 5-1). Mean dieldrin concentrations for 1980 were reported at 0.01 mg/kg (Forney 1982). Aldrin was not detected in carp. All aldrin-dieldrin sum concentrations for carp fall below the IJC objective of 0.3 mg/kg.

Dieldrin concentrations in Saginaw Bay channel catfish ranged from 0.00 to 0.29 mg/kg in 1973 and 1967, respectively (Table 5-1). The mean dieldrin concentration in channel catfish for 1980 was 0.02 mg/kg (Forney 1982). Aldrin was not detected. The aldrin-dieldrin sum for channel catfish for all years is below the IJC objective concentration of 0.3 mg/kg.

Mean dieldrin concentrations for Saginaw Bay channel catfish and common carp fillets are presented in Figure 5-18. These results show that channel catfish had consistently higher mean dieldrin concentrations than did common carp (Schmitt et al. 1981, 1983). However, both species exhibited higher concentrations during the early 1970s compared to those in the late 1970s.

Mean dieldrin concentrations for Saginaw Bay yellow perch ranged between 0.01 and 0.04 mg/kg (Table 5-1). For perch captured in areas other than Saginaw Bay, mean dieldrin concentrations ranged between 0.01 and 0.35 mg/kg. The high concentration of 0.35 mg/kg was detected in yellow perch from Alpena, Michigan, in 1979 (Schmitt et al. 1983). Aldrin was not detected in any samples of yellow perch. With the exception of the high concentration from Alpena in 1979, all yellow perch had aldrin-dieldrin sums below the IJC objective concentration of 0.3 mg/kg.

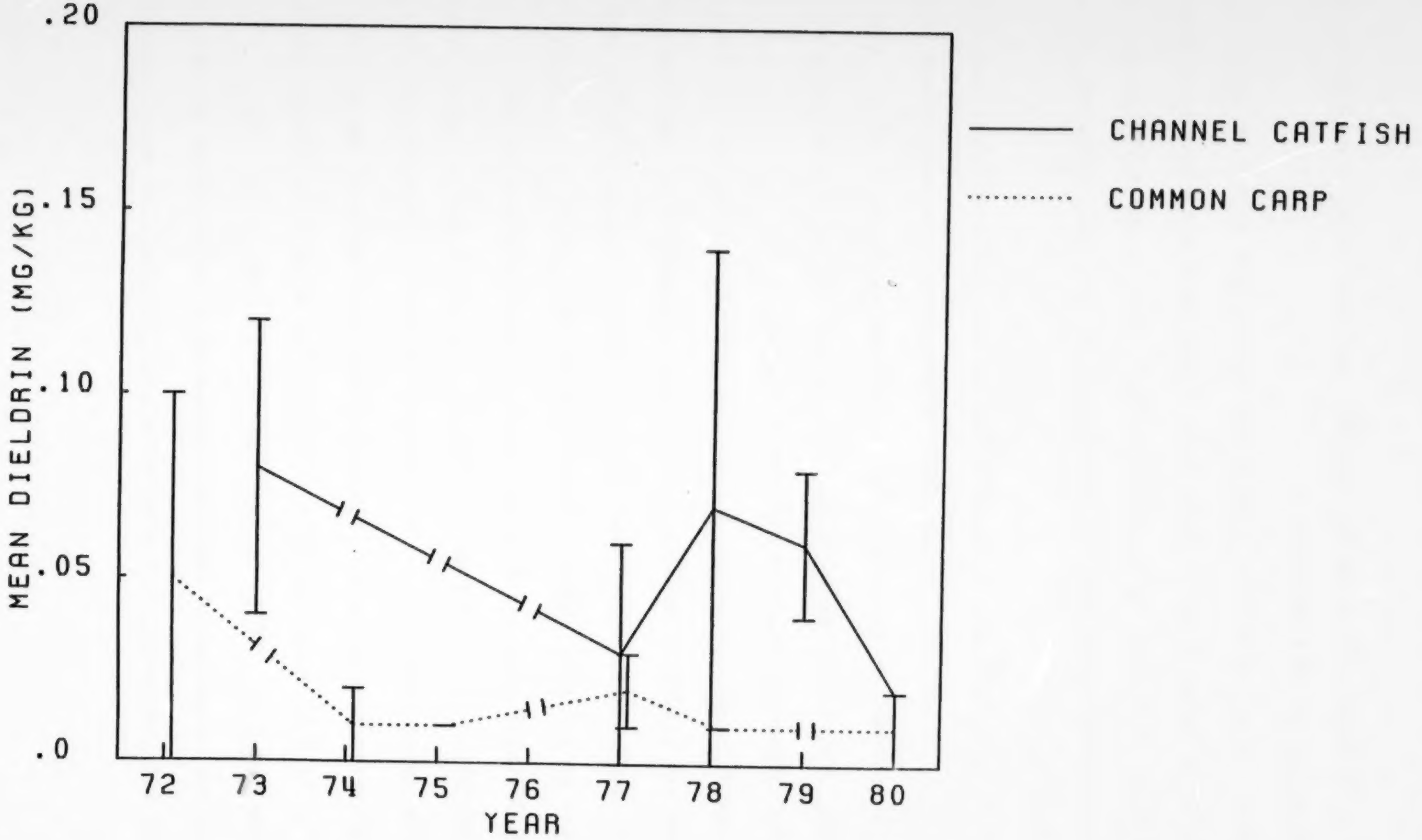

Figure 5-18. Yearly mean dieldrin concentrations (mg/kg) in Saginaw Bay channel catfish and common carp fillets, 1972-1980. Error bars are ± one standard deviation.

Lake trout collected at Alpena, Michigan, in 1979 had the highest dieldrin concentration detected in any species from Lake Huron at 0.50 mg/kg (Table 5-1). Other high dieldrin concentrations for lake trout were also observed for Alpena, Michigan, fish (Table 5-1). As indicated for PCB, mean concentrations of dieldrin were highest in larger size classes of lake trout (Table 5-1). Dieldrin concentrations of 0.34, 0.31, and 0.29 mg/kg were reported for lake trout in 1977, 1979, and 1978, respectively. Aldrin was reported in lake trout from 1977 through 1979, ranging from trace amounts to 0.014 mg/kg (D. DeVault, personal communication, Great Lakes National Program Office, USEPA). Lake trout from 1977 through 1979 had aldrin-dieldrin sums in excess of the IJC objective of 0.3 mg/kg; these concentrations, however, were for whole fish and not for the edible portion. However, lake trout from Saginaw Bay and the main lake in 1980 had sums lower than the IJC objective concentration.

For the remainder of fish species, only single means for bloater collected near Goderich, Ontario, (0.38 mg/kg) in 1974 and offshore splake (0.48 mg/kg) in 1975 had aldrin-dieldrin sums above the IJC objective concentration. Lower concentrations for dieldrin have been reported for bloater since 1974.

Mean dieldrin concentrations in northern Lake Huron lake trout, lake whitefish, and walleye are presented in Figure 5-19. These results indicate that walleye usually had the lowest mean dieldrin concentrations. Lake whitefish exhibited a high mean dieldrin concentration in 1973; however, lake trout showed the highest concentrations of dieldrin during 1978.

Mercury

Although mercury is not an organic contaminant, this parameter has been included because of its interest to fishery biologists. Highest mean mercury

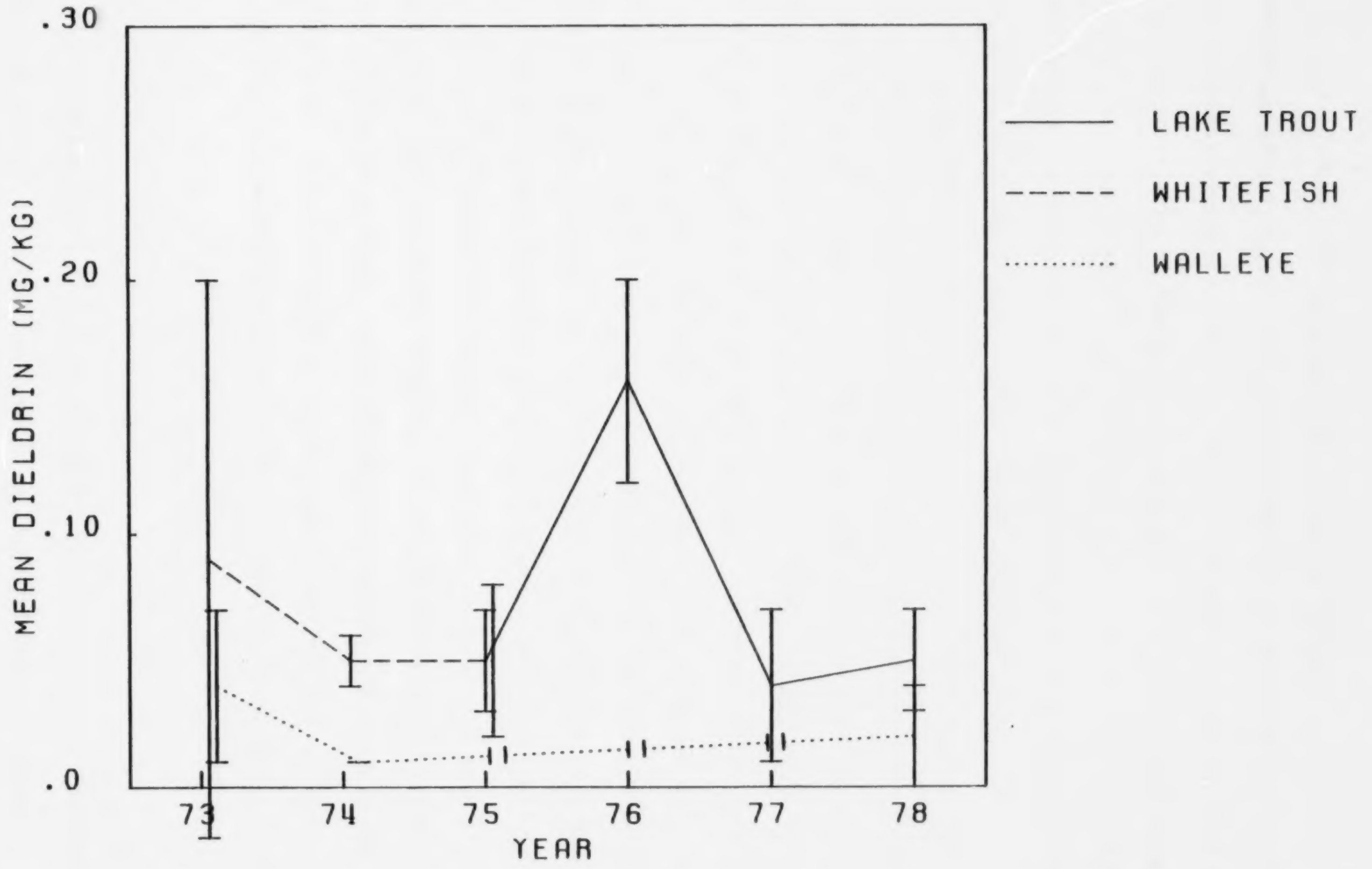

Figure 5-19. Comparison of yearly mean dieldrin concentrations (mg/kg) in Northern Lake Huron fish fillets, 1973-1978. Error bars are ± one standard deviation.

levels (Table 5-1) were detected in walleye (0.69, 0.55, and 0.52 mg/kg in 1978, 1973, and 1974, respectively). Other high mercury concentrations have been reported in northern pike (0.40 mg/kg) in 1974; at 0.37 mg/kg for coho salmon in 1980, lake trout in 1975, and chinook salmon in 1980; and at 0.34 mg/kg for yellow perch in 1974 and coho salmon in 1975 (Table 5-1). Walleye contained substantially greater amounts of mercury than other fish (Fig. 5-20). However, no definite conclusion can be drawn from this observation in terms of weight or lipids due to incomplete data. Saginaw Bay channel catfish exhibited considerably higher mean mercury concentrations than did common carp (Fig. 5-21).

High mercury concentrations were found in walleyes collected from northern Lake Huron and Georgian Bay, indicating possible contamination sources in these areas. Other fish with high mercury concentrations occurred in a range of localities (Saginaw Bay, offshore waters, southern Lake Huron, and Goderich, Ontario). Only walleye were in excess of the 0.5 mg/kg IJC objective concentration; where the last year of collection in 1978 also showed a concentration in excess of 0.5 mg/kg.

Heptachlor-heptachlor epoxide

All Lake Huron fish were below the heptachlor-heptachlor epoxide objective of 0.3 mg/kg proposed by the IJC. The highest observed concentration for heptachlor was 0.03 mg/kg in Saginaw Bay common carp in 1979 (Table 5-1). The highest concentration of heptachlor epoxide was 0.14 mg/kg in 1968 from Saginaw Bay yellow perch (Table 5-1).

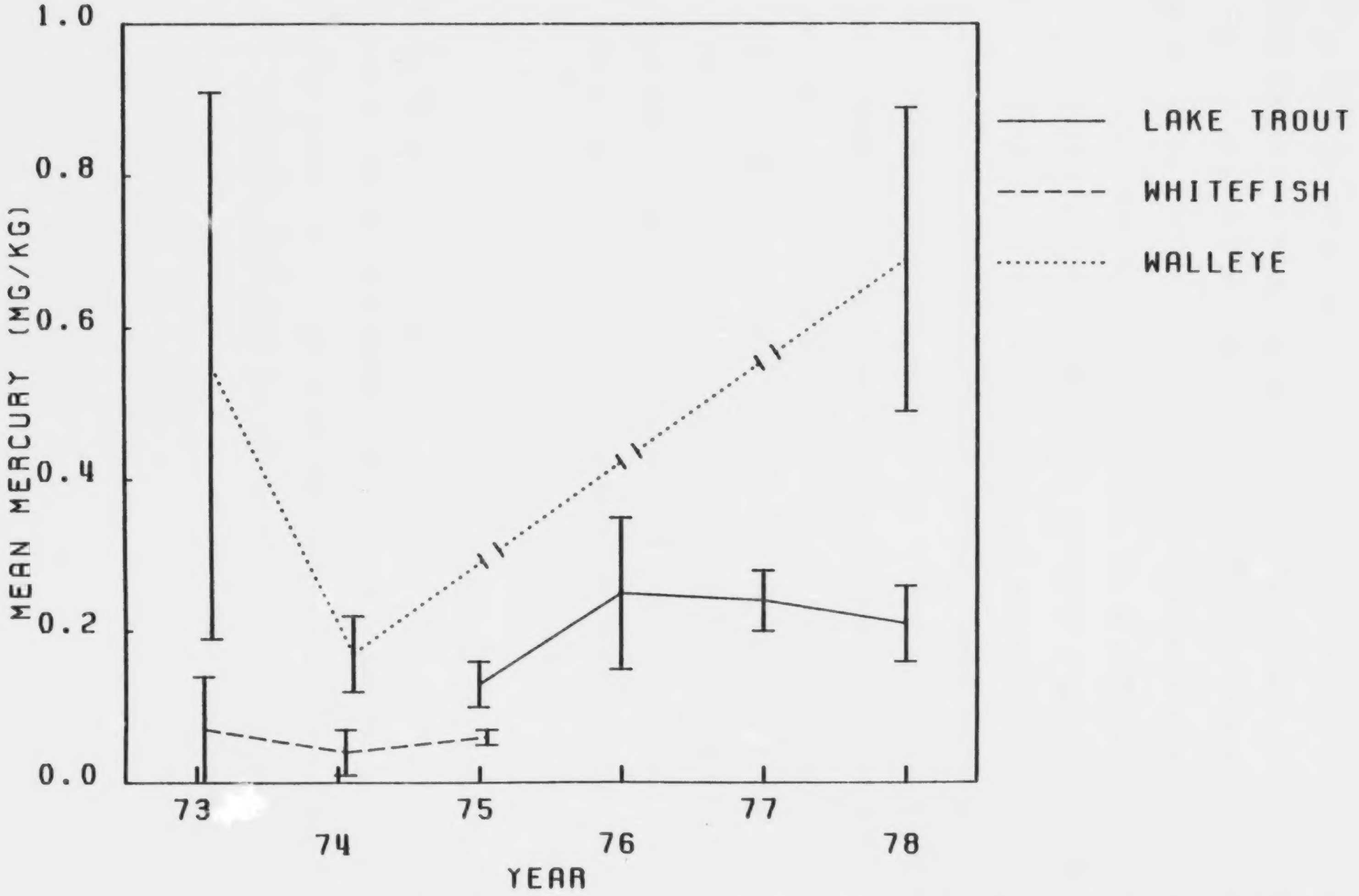

Figure 5-20. Comparison of yearly mean mercury concentrations (mg/kg) in Northern Lake Huron lake trout, lake whitefish, and walleye fillets, 1973-1978. Error bars are ± one standard deviation.

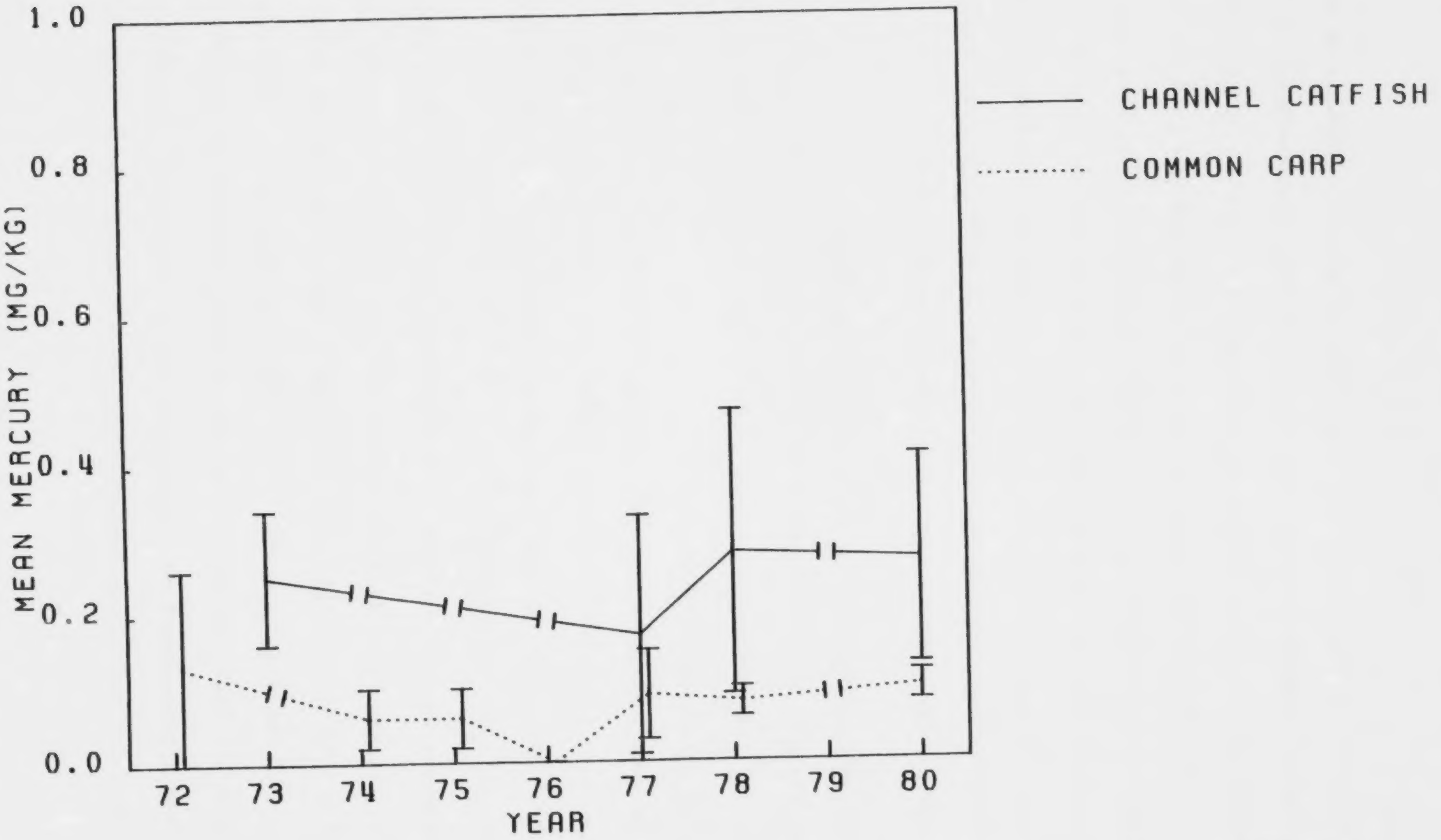

Figure 5-21. Yearly mean mercury concentrations (mg/kg) in Saginaw Bay fish fillets, 1972-1978. Error bars are ± one standard deviation.

Chlordane

Chlordane is reported as the sum of its technical components or as individual chlordane components: cis- and trans-nonachlor, oxychlordane, or cis- and trans-chlordane. Highest concentrations were in bloater (0.49 and 0.30 mg/kg) in 1974 from the northern sector of the lake (Armstrong and Lutz 1977). All subsequent concentrations have been lower. Oxychlordane has been reported only recently where the highest concentration of 0.07 mg/kg was detected in 1979 for lake trout collected near Alpena (Table 5-1). Cis- and trans-chlordane have been reported from trace amounts to 0.35 mg/kg in 1979 lake trout (Table 5-1). Cis-chlordane was consistently higher than trans-chlordane.

HCB, alpha-BHC, Toxaphene, Endrin, Lindane, and Dioxin

The highest hexachlorobenzene (HCB) concentration of 0.03 mg/kg was reported for lake trout from Alpena in 1977. Recent reports show only trace amounts or not detected (Table 5-1).

Alpha-BHC concentrations were recorded at 0.29 mg/kg and 0.31 mg/kg in Saginaw Bay channel catfish (1969) and common carp (1970), respectively. Since then, alpha-BHC has been reported at concentrations usually an order of magnitude lower (Table 5-1).

Toxaphene was not detected in fish samples during 1967, 1968, 1971, 1973, and 1974. It was first detected during 1977 in three species. Lake trout captured at Alpena, Michigan, had the highest mean concentration reported of 9.00 mg/kg (Schmitt *et al*. 1983). This report is the highest toxaphene level reported in any fish species from the Great Lakes (Schmitt *et al*. 1983). White sucker from Alpena showed mean concentrations of 0.33 mg/kg, and yellow perch from Saginaw Bay had a mean concentration of 0.35 mg/kg (Table 5-1). In 1979, Saginaw Bay common carp and yellow perch contained concentrations of 2.01 and 0.20 mg/kg, respectively. Also, yellow perch from Alpena contained 1.50 mg/kg (Table 5-1). In 1980, coho salmon were reported to contain measurable quantities of a toxaphene-like material at a mean concentration of 1.50 mg/kg (Table 5-1).

Schmitt et al. (1981, 1983) found concentrations of endrin ranging from trace amounts to 0.01 mg/kg in fish species predominantly from Saginaw Bay. All reported endrin concentrations were below the IJC objective of 0.3 mg/kg.

Henderson et al. (1969) found lindane in trace concentrations to 0.11 mg/kg in several species from Saginaw Bay. All concentrations for lindane were below the IJC objective of 0.3 mg/kg.

Dioxin residues in fish from Saginaw Bay are reported in Table 5-3. In general, common carp and channel catfish showed the highest dioxin concentrations of the fish species analyzed (Table 5-3). The highest dioxin concentration of 153.0 ng/kg was reported for common carp captured at the mouth of the Saginaw River (USEPA-Region V 1978). Stalling et al. (1983) also reported a high dioxin concentration of 94.0 ng/kg in common carp collected near Bay City in 1979. Dioxin residues in catfish of 56.0, 30.0, and 24.0 ng/kg were reported by FWS (1981), USEPA-Region V (1978), and Gledhill (1978), respectively. Dioxin was reported at 11.0 ng/kg in yellow perch from the Saginaw River mouth (USEPA-Region V 1978) but was not detected in three other yellow perch analyses (Gledhill 1978, USEPA-Region V 1978). Generally highest dioxin concentrations were found in fish near the Saginaw River mouth and Bay City.

Table 5-3. Dioxin (2,3,7,8-tetrachloro-dibenzo-p-dioxin) in Saginaw Bay fish.

Year	Locality	Species	Concentration (LOD)-ng/kg	Source
1978	Saginaw Bay	Perch	ND (10.0)	Gledhill (1978)
1978	Saginaw Bay	Perch	ND (10.0)	Gledhill (1978)
1978	Saginaw Bay	Catfish	24.0 (10.0)	Gledhill (1978)
1978	Saginaw River Mouth	Carp	153.0 (13.0)	USEPA-Region V (1978)
1978	Saginaw River Mouth	Channel Catfish	30.0 (6.0)	USEPA-Region V (1978)
1978	Saginaw River Mouth	Yellow Perch (2 fish)	11.0 (4.0)	USEPA-Region V (1978)
1978	Saginaw Bay	Sucker (2 fish)	4.0 (2.0)	USEPA-Region V (1978)
1978	Saginaw Bay	Yellow Perch (2 fish)	ND (3.0)	USEPA-Region V (1978)
1978	Saginaw Bay	Sucker	9.0	FWS (1981)
1978	Saginaw Bay	Catfish	22.0	FWS (1981)
1978	Saginaw Bay	Catfish	56.0	FWS (1981)
1979	Saginaw Bay - Bay City	Carp (2 fish)	94.0 (1.0-3.0)	Stalling *et al*. (1983)
1979	Saginaw Bay - Bayport	Carp (2 fish)	27.0 (1.0-3.0)	Stalling *et al*. (1983)

Gledhill. 1978. Analyses on skinless fillets.
USEPA - Region V. 1978. Analyses on skinless fillets.
Fish and Wildlife Service. 1981. Analyses on fish fillets.
Stalling *et al*. 1983. Analyses on whole fish.

Other Contaminants

In addition to the organic residues reported in Table 5-1 many other contaminants have been detected. Armstrong and Lutz (1977) detected traces of methoxychlor in bloater, slimy sculpin, and burbot. Other compounds detected in bloater at Mackinac Island or Goderich were biphenyl, naphthalene and methyl naphthalenes, phenanthrene and methyl phenanthrenes, diethyl phthalate, dibutyl phthalate, di-2-ethylhexylphthalate, trichlorobenzene, tetrachlorobenzene (2 isomers), pentachlorobenzene, octachlorobiphenyl (3 isomers), octachlorostyrene, cis- and trans-chlordane, cis- and trans-nonachlor, toxaphene components ($C_{10}H_8Cl_{7,8}$,trans-), and methyl benzothiophene. Higher concentrations were found in the larger size classes. Clark *et al*. (1982) found trace amounts of pentachlorophenyl methyl ester in 1980 collections of coho salmon from Tawas City, Michigan. Kuehl *et al*. (1976) reported octachlorostyrene, decachloroethylbenzene, and isomers of hepta- and hexachlorostyrene in Lake Huron walleye, but results were not quantified on a wet-weight basis. Gledhill (1978) detected PBB (polybrominated biphenyl) in two yellow perch samples from Saginaw Bay at 0.8 and 0.3 μg/kg and in Saginaw Bay catfish at 21.0 μg/kg (LOD 0.3 μg/kg). Stalling *et al*. (1983) detected dibenzofuran (2,3,7,8 tetrachloro-dibenzofuran) residues in 1979 samples of Saginaw Bay common carp (27.0 and 5.0 ng/kg) and Lake Huron lake trout (32 ng/kg). Stalling *et al*. (1983) also identified four other chlorinated dibenzofurans in these samples.

Compounds which were sought but not detected are given below. Henderson *et al*. (1969) did not detect chlordane in common carp, white sucker, channel catfish, and perch in 1967 and 1968. Methyl mercury was not detected in Lake Huron common carp (Henderson *et al*. 1972). Reinke *et al*. (1972) did not detect aldrin, heptachlor, heptachlor epoxide, endrin, and chlordane at significant levels but did not specify in which samples. Armstrong and Lutz (1977) did not detect BHC (alpha and gamma) and p,p'DDMV in burbot. Sills and Allen (1976) found no 3-trifluoro-methyl-4-nitrophenol (TFM) in Lake Huron chinook salmon. Chlordane, lindane, methoxychlor, hexachlorobenzene, hexachlorobutadiene, dibutyl-n-phthalate, 2,2-diethylhexylphthalate, and polybrominated biphenyls were not found at detectable levels in any fish analyzed in 1974 and 1975 (Mich. Water Res. Comm. 1975). Lindane, aldrin, and heptachlor were not detected in fish samples in 1974 (Ont. Ministry of the Environment 1976). Clark *et al.* (1982) did not detect mirex or dacthal in Lake Huron coho salmon (LOD .005 mg/kg).

Long-term Trends and Regional Comparisons of Organic Contaminants in Lake Huron Fish

Long-term contaminant trends are available for several Lake Huron fish species. Although the Lake Huron contaminant data set is of considerable size, construction of coherent time-series trends was complicated by the three non-comparable sample preparations used in analysis (edible portion, headless gutted fish, and whole fish) and collections from numerous geographical sites. These complexities were resolved by sorting the data to species, preparation method utilized, and collection locality, enabling a substantial portion of the data set to be included in long-term analyses.

Another limitation of this data set within the above framework was analyses of different size classes from year to year. Resultant contaminant concentrations were reported for fish which exhibited moderately wide ranges of body weight and lipid weight (derived from % lipid extracted). To determine the effect of fish size on concentrations in time-series trends, the relationship between PCB concentrations and lipid-weight PCB concentrations (PCBs expressed in terms of lipid content) was investigated. PCBs were chosen because of their lipophilic nature and because data were available to calculate lipid-weight concentrations for the major species examined in long-term trends.

A significant positive correlation ($r = 0.65$, $p < 0.01$, d.f. = 148) was obtained for PCB concentrations versus lipid-weight PCB concentrations. Time-series trends using lipid-weight PCB concentrations were strikingly similar to those of PCB concentrations, and the results of log-linear regression analyses indicated that trends were not significantly different from those presented below. Similarly, regional comparisons were not significantly altered. Ranges of body weight (kg) and lipid extracted (%), respectively, are presented for species used in these analyses and are as follows: Saginaw Bay common carp fillets 1.9-5.3, 6.9-11.4; whole Saginaw Bay common carp 0.8-1.8, 7.0-15.8; Saginaw Bay catfish fillets 0.7-5.3, 8.4-11.4; whole Saginaw Bay catfish 0.6-0.9, 13.4-29.5; whole Saginaw Bay yellow perch 0.1-0.2, 2.4-4.9; Saginaw Bay lake trout fillets 1.6-3.0, 9.3-12.1; northern Lake Huron lake trout fillets 1.0-1.1, 6.1-7.1; and offshore headless, gutted lake whitefish 0.7-1.3, 3.7-17.1 (Table 5-2).

The ideal data set for long-term trend analysis should be composed of fish with defined ranges of body weight and % lipid extracted. A collection strategy with these rigid objectives was infrequently pursued in the past, but it should be considered for future monitoring. Similarly, because the Lake Huron data set has been compiled from numerous authors and agencies, this approach is not presently feasible for Lake Huron.

The longest and most complete time-series trend for PCB contamination is for common carp collected in Saginaw Bay. Mean PCB concentrations in common carp over time resemble a parabolic function with high PCB concentrations in the early 1970s, lower concentrations during the mid-1970s, and increasing concentrations through the present. Long-term PCB monitoring in whole and fillet common carp show good agreement. Though log-linear regression ($\log_{10}$ transformed data) indicated no significant trend ($p < 0.05$) for PCB concentrations in common carp, most recently measured concentrations are relatively high.

Channel catfish fillets show high PCB concentrations in 1973 and 1980, with low, consistent values from 1977 through 1979. No statistically significant ($p < 0.05$) trend was observed for channel catfish. Whole yellow perch collected from Saginaw Bay show a significant decrease ($p < 0.05$) in PCB concentrations between 1969 and 1979. Yellow perch fillet analyses were considerably different, exhibiting much lower, uniform concentrations over time.

Statistically significant trends ($p < 0.05$) for PCBs were not observed in any other fish species. However, coho salmon collected from the offshore zone showed slightly increasing mean concentrations between 1968 and 1975. Analyses of whole lake trout from Alpena, Michigan, showed increasing mean PCB concentrations between 1977 and 1979. However, lake trout fillets from the northern basin show a considerable reduction in mean PCB concentrations from 1977 to 1978. Lake whitefish collected from offshore Lake Huron exhibited PCB concentrations that were relatively low and uniform between 1969 and 1976. From sparse data, chinook salmon, bloater, and brown trout showed decreases in mean PCB concentrations between 1971 and 1980.

Generally, common carp and channel catfish collected from Saginaw Bay contained the highest PCB concentrations observed in Lake Huron fish; however, other species such as chinook salmon also contained high levels sporadically. Saginaw Bay common carp exhibited higher mean PCB concentrations than did specimens from the southern basin during 1975. Channel catfish were not analyzed for PCBs in fish other than from Saginaw Bay. Yellow perch collected in Saginaw Bay typically had similar or higher PCB concentrations compared to those collected from other areas of the lake. Saginaw Bay lake trout also contained higher mean concentrations than did lake trout from the northern basin.

Typically, fish analyzed from the southern basin had higher mean PCB concentrations than those from the northern basin, e.g., lake trout, although some species such as bloater exhibited the converse. Fish from the North Channel usually contained the lowest PCB concentrations when comparisons could be made to fish from Georgian Bay and the open lake. Fish from Georgian Bay and the main lake showed comparable values but each showed high values from one time to another.

Most Lake Huron fish species show decreasing DDT-R concentrations in time-series trends. In Saginaw Bay, whole common carp, channel catfish, and yellow perch exhibit lower mean DDT-R concentrations during post-1970 compared to pre-1970. A significant decrease ($p < 0.05$) was indicated by log-linear regression analysis for Saginaw Bay whole yellow perch between 1967 and 1979. Statistically significant trends ($p < 0.05$) were not observed for any other species. Highest DDT-R concentrations in lake whitefish, walleye, and coho salmon were recorded prior to 1970, with lower mean concentrations observed since 1970. Similarly, bloater, chinook salmon, splake, and brown trout have had lower PCB concentrations since 1973.

The highest DDT-R concentrations reported for Lake Huron fish were detected in species from Georgian Bay and the open lake. Regional differences, however, were not always consistent. Highest DDT-R concentrations in lake trout, bloater, and yellow pickerel were observed in Georgian Bay fish, whereas the highest mean DDT-R concentrations in coho salmon, walleye, and whitefish were detected in open lake fish. The North Channel also contained some species with comparatively high DDT-R concentrations. Saginaw Bay yellow perch and lake trout exhibited higher mean DDT-R concentrations than those from the main lake.

No statistically significant trends ($p < 0.05$) were indicated for dieldrin by log-linear regression analysis. Dieldrin concentrations have been monitored since 1967 for some species; however, the highest dieldrin values have been reported since 1975. Although higher values have been recorded during more recent surveys, dieldrin concentrations over time are rather uniform for most species. Fish from Georgian Bay and the North Channel typically contained dieldrin concentrations similar to or below those from the open lake. The highest mean dieldrin concentrations were recorded for lake trout and yellow perch from Alpena, Michigan. Considering only the offshore waters of the main lake, fish from the southern basin had slightly higher mean concentrations compared to fish from the northern portion of the lake. Species collected from Saginaw Bay generally had lower dieldrin concentrations than those from Alpena, Michigan, and Georgian Bay.

Mercury concentrations in most species were usually uniform and stable in time series trends; however, the highest mercury values were reported between 1973 and 1980. Walleye contained the highest mercury concentration recorded for any Lake Huron fish species in 1980. Similarly, the highest mercury concentrations in coho salmon, northern pike, lake trout, and chinook salmon were recorded since 1973. Some large mercury values were observed in fish from Saginaw Bay and the southern basin, but a preponderance of high concentrations were detected in fish from the northern portion of the lake and Georgian Bay, e.g., walleye.

Summary

Many organic contaminants have been detected in Lake Huron fish. Of the contaminants reported that have had objective concentrations established by the International Joint Commission, PCBs, DDT-R, dieldrin-aldrin sums, and mercury concentrations in various species of Lake Huron fish have exceeded the objective. Table 5-4 presents the years that particular compounds were in excess of the IJC objectives for individual fish species and whether the objective was exceeded during the last year the contaminant was sought.

Through the most recent sampling period for each species, all Lake Huron fish species contained PCB concentrations higher than the IJC objective of 0.1 mg/kg (Table 5-4). Although high PCB concentrations were observed in recent years, no individual species showed significantly increasing PCB concentrations. In fact, Saginaw Bay whole yellow perch exhibited a significantly decreasing trend ($p < 0.05$) in PCB concentrations. It appears that Saginaw Bay species generally contained the highest PCB concentrations recorded.

Most Lake Huron fish contain considerably lower mean DDT-R concentrations since 1973 compared to levels prior to 1973. However, only Saginaw Bay yellow perch exhibited a significant decrease in DDT-R concentrations over time. Through the most recent sampling period for all species, only bloater, splake, and burbot possessed DDT-R concentrations above the IJC objective of 1.0 mg/kg (Table 5-4). Typically, highest DDT-R concentrations were observed in fish from Saginaw Bay.

Dieldrin-aldrin sum concentrations were in excess of the IJC objective of 0.1 mg/kg in yellow perch, lake trout, bloater, and splake (Table 5-4). Although most high concentrations were recorded during the mid-to late 1970s, only yellow perch and splake were above the IJC objective for the last period

Table 5-4. Summary of fish species and years when organic concentrations were in excess of the International Joint Commission objectives.

Compound and IJC Objective	Species	Years
PCB (0.1 mg/kg)		
	Carp	1969-1980*
	Channel catfish	1969-1980*
	Yellow perch	1968-1979*
	Lake trout	1969-1980*
	Bloater	1969-1978*
	Lake whitefish	1969-1976*
	Walleye	1969-1980*
	Coho salmon	1968-1980*
	Chinook salmon	1973-1980*
	Brown trout	1973-1980*
	Splake	1969-1975*
	Rainbow trout	1968-1975*
	Cisco	1969-1976*
	Burbot	1974*
	Northern pike	1974*
DDT (1.0 mg/kg)		
	Carp	1967-1972
	Channel catfish	1966-1972, 1979
	Yellow perch	1967-1968, 1970
	Lake trout	1969-1979
	Bloater	1966, 1970-1978*
	Lake whitefish	1966, 1970
	Walleye	1966, 1969-1971
	Coho salmon	1971-1973
	Chinook salmon	1973-1974
	Brown trout	1973
	Splake	1969-1970, 1975*
	Rainbow trout	1968-1970
	Cisco	1969, 1975
	Burbot	1974*
Dieldrin-aldrin (0.1 mg/kg)		
	Yellow perch	1979*
	Lake trout	1977-1979
	Bloater	1974-1975
	Splake	1975*
Mercury (0.5 mg/kg)		
	Walleye	1973-1974, 1978*

*Most recent year of analysis.

those species were analyzed. Typically, fish from Alpena, Michigan, and Georgian Bay exhibited the highest mean dieldrin concentrations recorded.

Walleye was the only fish species observed in Lake Huron that had mercury concentrations above the IJC objective of 0.5 mg/kg (Table 5-4). Most of the highest concentrations have been recorded since 1973 from the northern basin of Lake Huron.

For other contaminants that have had objectives established, all Lake Huron fish contain concentrations below the IJC objectives.

The following recommendations are based on the strengths and limitations encountered in analyzing the present data set. Numerous factors are involved in reaching these recommendations; however, the primary goal is to establish long-term, organic concentration trends that can be sorted by species, locality, and size class for comparative purposes. A continuing monitoring program is the only means by which this can be accomplished. After this goal has been realized, appropriate statistical techniques can be applied for trend analysis and comparison on a regional basis.

In view of the overriding importance of human health as it relates to both sport and commercial fisheries, it is recommended that analyses of edible fish portions should be pursued for surveillance and monitoring. There appears to be a considerable difference in contaminant concentrations between whole versus fillet analyses, and monitoring of concentrations consumed appears to be the most critical. From the research biologist viewpoint, however, the study of fish contamination dynamics, utilizing whole fish, is necessary. However, we believe this is overshadowed by the consequences of human consumption if edible portion concentrations are unknown. A limiting factor to this recommendation is that the large existing data set for whole fish could not be utilized for assessment of public health risks as accurately as edible portion analyses. We do recommend the continuance of whole fish monitoring in its present framework to detect newly emerging contaminant problems.

Several needs for conducting contaminant monitoring programs become apparent by inspecting this data set of Lake Huron fish. We recommend that monitoring be conducted with the following aspects in mind. First, fish sampling and analyses should be conducted yearly for the construction of long-term trends. Within this framework, yearly samples should be consistently collected from specific localities, and the same fish species should be routinely monitored at each individual site. It is recognized that the same species is not found at every locality; however, specific species should be analyzed at a locality for internal consistency. For those species that occur throughout Lake Huron, comparisons could be made to identify contaminant point sources. Lake regions should be segmented so that specific sites can be monitored. As an example of this problem, Statistical Fishery District #4 (GLECS zones in Fig. 5-1) should be divided into at least three zones: inner and outer Saginaw Bay and the Lake Huron open waters to the international boundary. Lake trout species reported from Saginaw Bay are probably transient fish from the open lake zone and are not from inner Saginaw Bay, whereas common carp and channel catfish are comparatively non-transient residents of Saginaw Bay. This would allow the partitioning of Saginaw Bay which has distinctive fish contaminant problems.

We also suggest that salmonids should be collected yearly during fall runs and monitored at several sites for easier collection and surveillance of offshore conditions. More attention should be given to collecting and reporting the analyses of different size and age classes. This would provide, along with percent lipid extracted, trends for lipid-weight contaminant concentrations and concentrations for fish of different weight classes. There also seems to be a lack of fish specifically collected from the offshore waters, and sampling should be designed to collect species inhabiting the offshore zone.

We recommend that analyses of chlorinated organics and metals should be conducted using electron-capture gas chromatography. The samples should then be screened utilizing mass spectrometry. This procedure has been initiated by DeVault and Willford (1982).

It appears that PCB is the most frequently observed contaminant exceeding the IJC objective and that surveillance and study of PCB should be a priority concern. Some toxicants, such as toxaphene, PBB, and dioxin, need greater study and should also receive priority for monitoring.

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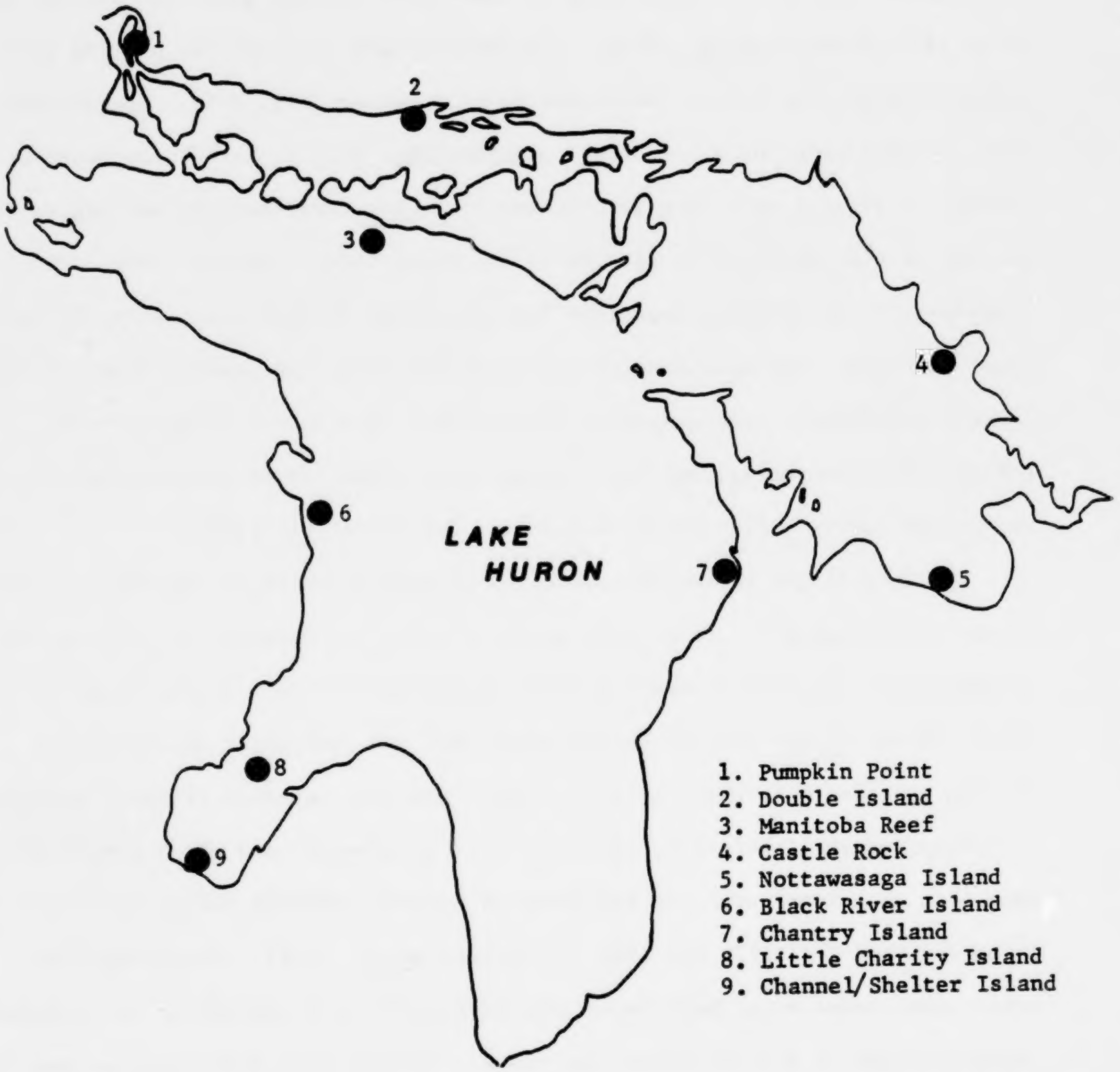
CHAPTER SIX

ORGANIC RESIDUES IN LAKE HURON HERRING GULL EGGS

Organic contaminant monitoring of Lake Huron herring gull eggs was initiated in 1974 (Weseloh et al. 1979). The largest data sets are for herring gull colonies located at Double Island and Chantry Island (Fig. 6-1). Sparse 1980 data are available for seven other colonies (Fig. 6-1) in Lake Huron (Weseloh unpubl.). Herring gull eggs were chosen to be monitored because herring gulls are one of the top predator species in the Great Lakes food web. They are considered to be suitable organisms for monitoring because they generally bioaccumulate higher concentrations of organics than other top predator species, are largely piscivorous, are generally nonmigratory, are easily censused on an entire population basis, and have ground nests which can be observed and eggs and chicks easily collected for monitoring (Gilman et al. 1978a).

Declines in the reproductive success of herring gulls in Lake Ontario led to the surveillance of other Great Lakes colonies for comparative purposes and to determine contaminant levels (Gilman et al. 1977). In a series of investigations, Gilman et al. (1978b) demonstrated that both intrinsic and extrinsic factors contribute to hatching efficiency. However, hatching failure, embryonic mortality, eggshell thinness, abnormal chick occurrence, and chick mortality have been associated with the incidence of organic residues (Gilbertson 1974, Gilbertson and Fox 1977, Fox 1976, Gilbertson et al. 1976). Comparing Great Lakes contaminant data, Lake Ontario herring gulls were exposed to the greatest concentrations of PCB and Mirex, and these compounds have been cited as possible causative factors for the array of breeding failures observed in Lake Ontario colonies (Gilman et al. 1977).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LAKE
HURON
1. Pumpkin Point
2. Double Island
3. Manitoba Reef
4. Castle Rock
5. Nottawasaga Island
6. Black River Island
7. Chantry Island
8. Little Charity Island
9. Channel/Shelter Island

Figure 6-1. Locations of Lake Huron herring gull colonies.

In regard to most organic compound levels, Lake Huron herring gull eggs contain concentrations between the extremes reported for the other Great Lakes. Similarly, in terms of hatchability, eggs per clutch, embryo mortality, chicks produced per mating pair, and chick mortality, Lake Huron colonies were within the range of values reported for the other Great Lakes (Gilman et al. 1977).

Organic Contaminant Levels in Herring Gull Eggs

Residue levels detected in Lake Huron herring gull eggs are presented by colony, date, and compound (Table 6-1). Each compound will be discussed separately.

PCBs

In the following investigations, PCBs were measured against a standard of Aroclor 1254 and 1260 mixed in equal portions. Results are reported on a wet-weight basis. Additional data for herring gull eggs and herring gull muscle at Chantry, Channel/Shelter, and Little Charity islands for Aroclor 1254 are presented by the Great Lakes Water Quality Board (1981) and Stalling et al. (1983).

At Double Island, PCBs in herring gull eggs were highest in 1977 (77.0 μg/g) with high concentrations also recorded for 1974 and 1975 (56.0 and 46.0 μg/g, respectively). Declining PCB concentrations were observed from 1977 through 1980. The highest PCB concentration recorded at Chantry Island was 86.0 μg/g in 1974 (Table 6-1). Lower concentrations have been reported since 1974; however, a PCB concentration of 64.0 μg/g was reported in 1977. Limited data for 1980 are available at the other seven colony sites (Table 6-1). PCB concentrations ranged from 69.6 μg/g at Channel/Shelter Island to 16.2 μg/g at Nottawasaga Island (Table 6-1). With the exception of the Manitoba Reef site, herring gull

Table 6-1. Mean organic residue concentrations (µg/g) in Lake Huron herring gull eggs, 1974-1980.

	CHANTRY ISLAND										DOUBLE ISLAND										
Compound	n	1974	± S.D.	1975	± S.D.	1977	± S.D.	1978	± S.D.	1979	1980	n	1974	± S.D.	1975	± S.D.	1977	± S.D.	1978	± S.D.	1979	1980
PCB	10	86.0	22.0	39.0	17.0	64.0	16.0	32.0	12.0	33.0	23.4	10	56.0	17.0	46.0	15.0	77.0	48.0	33.0	9.5	28.0	17.4
DDT-R	10	21.9		12.1		13.3		6.1		0.06		10	14.9		16.2		20.4		7.1		0.06	
DDE	10	21.0	8.6	12.0	4.4	13.0	4.6	6.0	2.5		2.8	10	14.0	6.7	16.0	8.5	19.0	15.0	7.0	2.6		2.6
DDT	10	0.63	0.23	0.04	0.03	0.09	0.05	0.05	0.03	0.06		10	0.55	0.28	0.17	0.10	0.09	0.07	0.09	0.02	0.06	
DDD	10	0.29	0.07	0.02	0.03	0.23	0.08					10	0.36	0.09	0.02	0.02	1.26	0.12				
Mirex	10	2.2	2.1	0.48	0.56	0.34	0.22	0.26	0.33	0.3	0.16	10	0.52	0.22	0.55	0.67	0.55	0.57	0.16	0.22	0.3	0.06
Photomirex	10					0.14	0.08	0.10	0.12			10					0.21	0.20	0.07	0.07		
Dieldrin	10	0.47	0.18	0.31	0.20	0.57	0.25	0.22	0.09	0.28		10	0.53	0.16	0.41	0.18	0.51	0.24	0.22	0.12	0.32	
Heptachlor Epox.	10	0.16	0.05	0.07	0.03	0.19	0.05	0.10	0.04			10	0.16	0.03	0.09	0.05	0.19	0.13	0.10	0.04		
Oxychlordane	10					0.30	0.11	0.16	0.09			10					0.36	0.33	0.17	0.09		
BHC	10					0.04	0.03	0.03	0.03			10					0.05	0.02	0.02	0.02		
HCB	10	0.47	0.23	0.17	0.05	0.17	0.08	0.14	0.07			10	0.30	0.08	0.24	0.08	0.21	0.05	0.09	0.05		
2,3,7,8 TCDD												10										$14.0 \pm 2.4 \times 10^{-6}$
Chlorobenzenes																						
1,2,4,5 tetrachlorobenzene	11							ND				10							ND			
1,2,3,4 tetrachlorobenzene	1							0.02				10							ND			
Pentachlorobenzene	5							0.03	0.02			8							0.02	0.004		
Hg	10	0.24	0.07	0.23	0.08	0.22						10	0.19	0.05	0.31	0.12	0.40					
Pb	10					0.41						10					0.12					

(Continued)

Legend:
ND = not detected
Blank = no data

Data Sources:
Data from 1974-1978: Weseloh *et al.* (1979).
Data from 1979: Great Lakes Water Quality Board (1981).
Data from 1980: Weseloh (unpublished).

Table 6-1. (Concluded).

	CHANNEL SHELTER ISLAND			LITTLE CHARITY ISLAND			PUMPKIN POINT		NOTTAWASAGA ISLAND		MANITOBA REEF		BLACK RIVER ISLAND		CASTLE ROCK	
Compound	n	1980	± S.D.	n	1980	± S.D.	n	1980	n	1980	n	1980	n	1980	n	1980
PCB	10	69.6		10	41.9		10	26.4	10	16.2	10	43.1	10	28.7	10	17.6
DDT-R																
DDE	10	8.9		10	6.4		10	3.1	10	2.1	10	6.4	10	5.8	10	3.4
DDT																
DDD																
Mirex	10	0.19		10	0.08		10	0.13	10	0.31	10	0.21	10	0.17	10	0.12
Photomirex																
Dieldrin																
Heptachlor Epox.																
Oxychlordane																
BHC																
HCB																
2,3,7,8 TCDD	10	$86.0 \pm 2.5 \times 10^{-6}$			$43.0 \pm 3.6 \times 10^{-6}$											
Chlorobenzenes																
1,2,4,5 tetrachlorobenzene																
1,2,3,4 tetrachlorobenzene																
Pentachlorobenzene																
Hg																
Pb																

Legend:
ND = not detected
Blank = no data

Data Sources:
Data from 1974-1978: Weseloh et al. (1979).
Data from 1979: Great Lakes Water Quality Board (1981).
Data from 1980: Weseloh (unpublished).

eggs collected in 1980 at colonies in Saginaw Bay had PCB concentrations 2-4 times higher than colonies at other localities.

DDT, DDE, and DDD

DDT and its degradation products, DDE and DDD, have been summed and are included in Table 6-1 as DDT-R. Data for DDE and DDD are sparse for all years and therefore DDT-R concentrations may be somewhat misleading. Because complete information was not provided by the various authors cited, it was assumed that values for DDT, DDE, and DDD were for the para, para' isomers.

Highest DDT concentrations were reported in herring gull eggs from both Double and Chantry islands in 1974 (0.55 and 0.63 μg/g, respectively). Since 1974, each colony showed decreasing DDT concentrations to 0.06 μg/g in 1979 (Table 6-1).

DDE was found to be the most abundant DDT degradation product in these studies of herring gull eggs. At Double Island DDE increased from 14.0 μg/g in 1974 to 19.0 μg/g in 1977 (Table 6-1). A considerably lower DDE concentration of 2.6 μg/g was reported in 1980. At Chantry Island, DDE decreased from 21.0 μg/g in 1974 to 2.8 μg/g in 1980 (Table 6-1). In 1980, the highest DDE concentration was reported from the Channel/Shelter Island colony at 8.9 μg/g (Table 6-1). High concentrations up to 6.4 μg/g were reported for the colonies at Little Charity Island and Manitoba Reef and 5.8 μg/g for the colony at Black River Island.

For the Double Island colony, DDD concentrations in herring gull eggs were highest in 1977 at 1.26 μg/g (Table 6-1). At Chantry Island, DDD was highest in 1974 (0.29 μg/g) with lower concentrations since 1974.

Mirex

Mirex concentrations in herring gull eggs at Double Island were constant at 0.55 μg/g from 1974 through 1977 (Table 6-1). A much lower concentration of 0.06 μg/g was reported for 1980. At Chantry Island, a comparatively high Mirex concentration of 2.2 μg/g was observed in 1974. Much lower concentrations have been reported since 1974 (Table 6-1). The highest 1980 Mirex concentration of 0.31 μg/g was reported in eggs from Nottawasaga Island. Concentrations in eggs from other colonies ranged from 0.08 μg/g at Little Charity Island to 0.21 μg/g at Manitoba Reef.

Dieldrin

Dieldrin concentrations in Double Island eggs were highest in 1974 at 0.53 μg/g (Table 6-1). Another high concentration was reported in 1977 (0.51 μg/g); however, lower concentrations were recorded for dieldrin in 1978 and 1979 (Table 6-1). At Chantry Island, highest dieldrin concentrations in eggs were observed in 1977 (0.57 μg/g) with reduced concentrations reported in 1978 and 1979 (Table 6-1).

Heptachlor Epoxide

Heptachlor epoxide was reported at the highest concentration (0.19 μg/g) in 1977 for eggs collected from Double and Chantry islands (Table 6-1). Lower concentrations were reported for 1978 and 1979.

Dioxin

Dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) concentrations in eggs are available only for 1980 at Double, Channel/Shelter, and Little Charity islands (Table 6-1). Highest concentrations were observed in eggs from Channel/Shelter

Island (86.0×10^{-6} μg/g). Little Charity Island, also located in Saginaw Bay, showed concentrations in eggs as high as 43.0×10^{-6} μg/g, whereas Double Island eggs contained 14.0×10^{-6} μg/g (Table 6-1). In general, dioxin concentrations in Saginaw Bay herring gull eggs were 3-6 times higher than the site at Double Island.

Other Contaminants

Photomirex was detected at the highest concentration (0.21 μg/g) in eggs from Double Island (Table 6-1). The remainder of concentrations reported were considerably lower, ranging from 0.07 to 0.14 μg/g at Double and Chantry islands.

Oxychlordane concentrations for Double and Chantry islands' eggs were comparable for 1977 and 1978 (Table 6-1). Concentrations ranged from 0.16 to 0.36 μg/g with the latter concentration in eggs from Double Island.

BHC was recorded in low concentrations in eggs from Double and Chantry islands and ranged from 0.02 to 0.05 μg/g (Table 6-1). HCB showed steady declines from highs of 0.30 μg/g and 0.47 μg/g in Double and Chantry islands' eggs, respectively, in 1974 to 0.09 and 0.14 μg/g, respectively, in 1978 (Table 6-1).

Pentachlorobenzene was highest in Chantry Island eggs at 0.03 μg/g compared to 0.019 μg/g in those from Double Island. Chantry Island eggs contained 1,2,3,4 tetrachlorobenzene at 0.017 μg/g but was not detected in eggs from Double Island (Table 6-1). Eggs from neither colony contained detectable amounts of 1,2,4,5 tetrachlorobenzene.

The highest mercury concentration of 0.40 μg/g was recorded for eggs at Double Island in 1977 (Table 6-1). Mercury concentrations in Double and Chantry islands' eggs ranged from 0.19 μg/g to 0.40 μg/g.

Lead was reported in herring gull eggs from both island colonies in 1977 only (Table 6-1). The lead concentration in Chantry Island eggs was 0.41 μg/g and was considerably higher than the 0.13 μg/g concentration in those from Double Island. Dibenzofuran (2,3,7,8-tetrachloro-dibenzofuran) has been reported at a concentration of 15.0×10^{-6} μg/g in herring gull muscle from Channel/Shelter Island (Stalling et al. 1983).

Trend Analysis

Although the data sets for the major organic contaminants detected in herring gull eggs are fairly complete, these data do not represent long-term trends. However, trends between 1974 and 1980 are analyzed for the six years of data available.

PCBs

In Double Island eggs, high PCB concentrations were observed in 1974 and 1977 (Fig. 6-2). In Chantry Island eggs, the highest concentration was recorded in 1977 (Fig. 6-2). Regression analysis of log-transformed data shows a significant decrease ($p < 0.05$) in PCB concentrations at both colonies. In both cases, concentrations declined substantially after 1977.

DDT

Eggs from Double and Chantry islands exhibited highest DDT concentrations in 1974 with decreasing concentrations through 1979 (Fig. 6-3). Log-linear regression analysis showed a significant decrease ($p < 0.05$) in DDT for Double

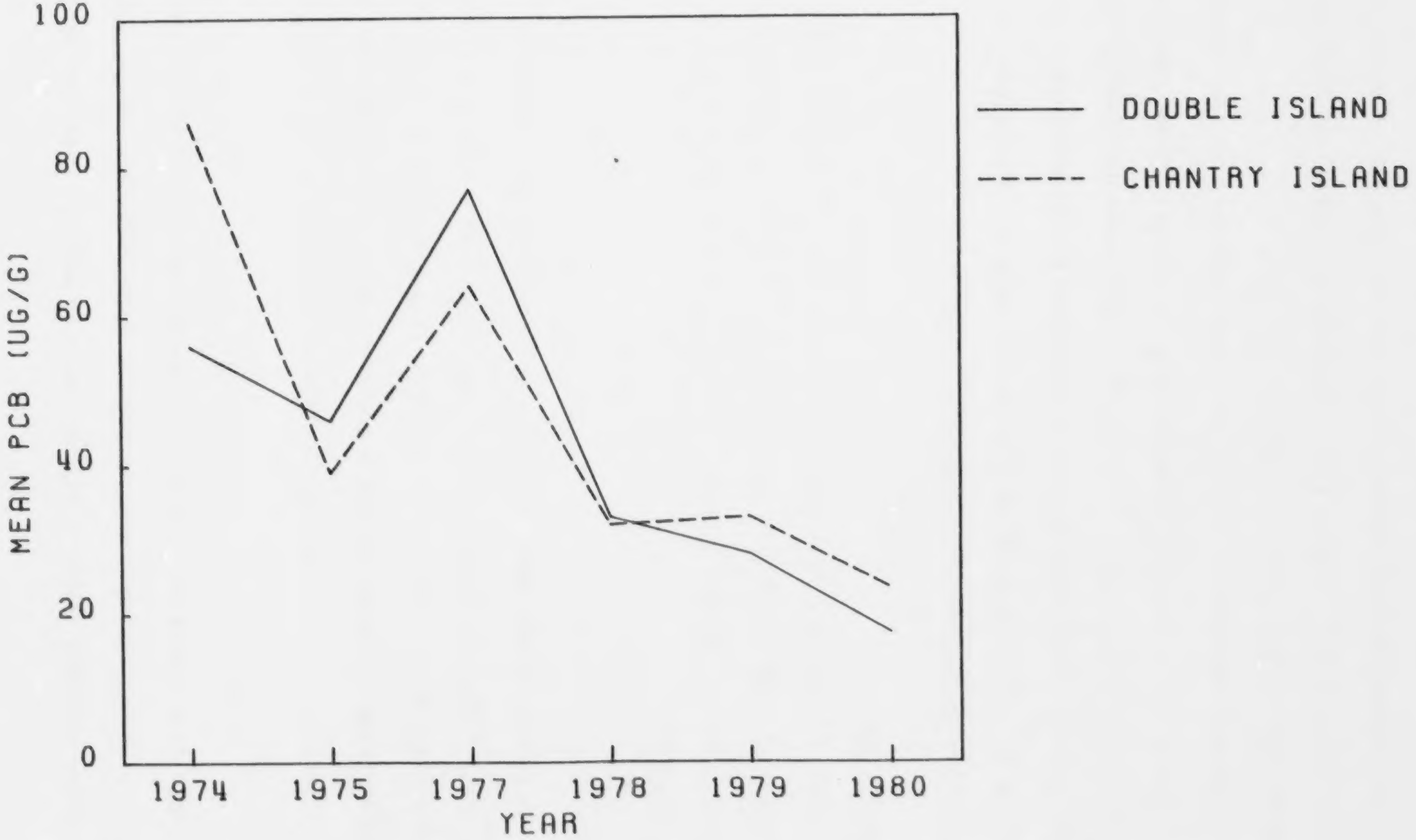

Figure 6-2. Mean PCB concentrations (µg/g) in herring gull eggs from Double and Chantry islands, Lake Huron, 1974-1980.

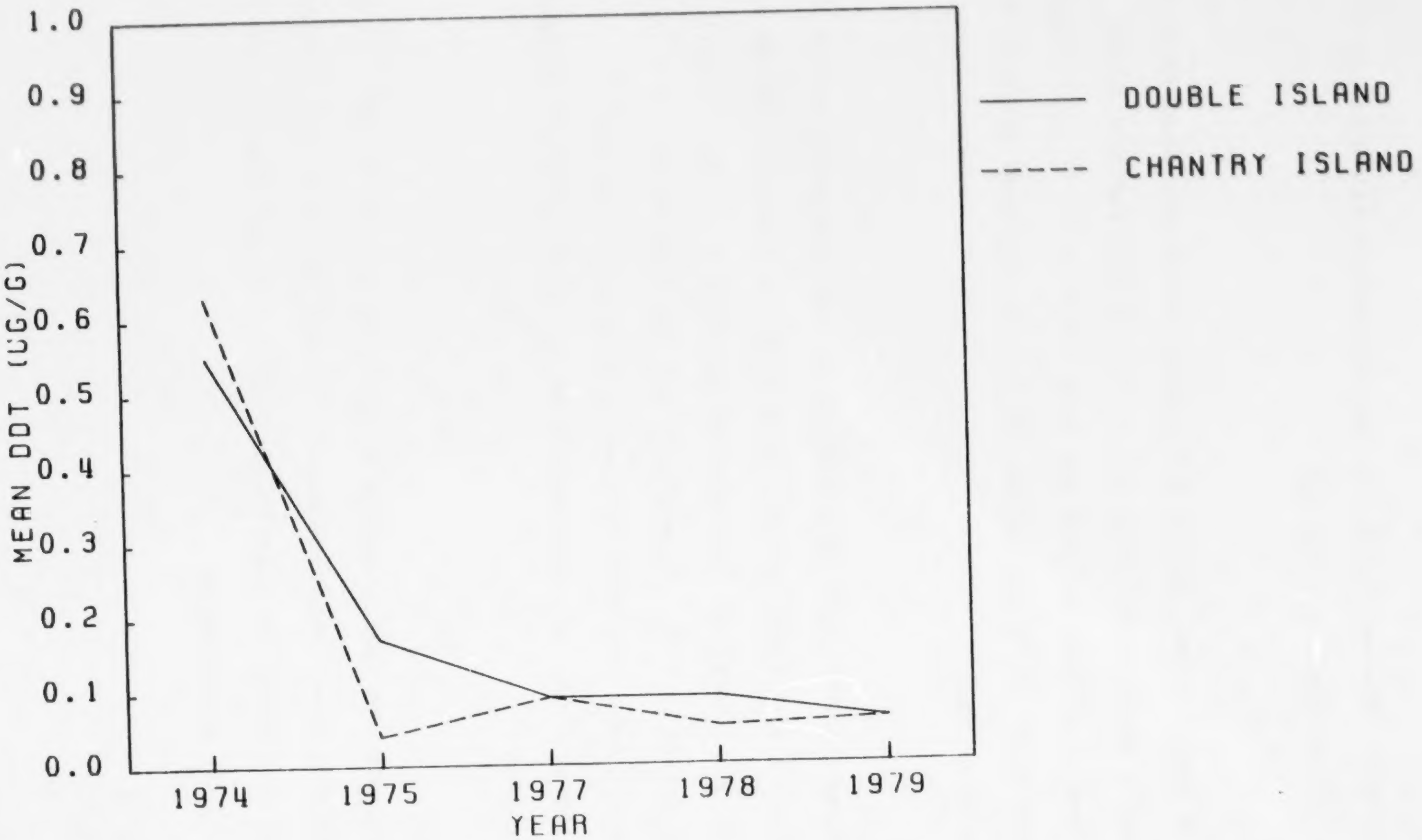

Figure 6-3. Mean DDT concentrations (µg/g) in herring gull eggs from Double and Chantry islands, Lake Huron, 1974-1980.

Island eggs. However, regression analysis was not statistically significant ($p < 0.05$) for Chantry Island eggs.

DDE

At Double Island, highest DDE concentrations were observed in 1977, whereas at Chantry Island highest mean concentrations were recorded in 1974 (Fig. 6-4). Log-linear regression analysis was significant ($p < 0.05$) and indicated a decrease in DDE in Chantry Island eggs but was not significant ($p < 0.05$) for Double Island eggs.

Mirex

Mirex concentrations were constant in eggs from Double Island from 1974 through 1977 with lower concentrations occurring from 1978 through 1980 (Fig. 6-5). A very high concentration was detected in herring gull eggs at Chantry Island in 1974. Between 1974 and 1980, concentrations have decreased. Substantial reductions were observed in Mirex concentrations, and log-linear regression analyses indicated significant decreases ($p < 0.05$) in eggs from both colonies.

Dieldrin

High dieldrin concentrations in eggs were observed in 1977 for both colonies with lower concentrations in 1978 and 1979 (Fig. 6-6). Regression analyses of dieldrin concentrations, however, were not statistically significant ($p < 0.05$) for either colony.

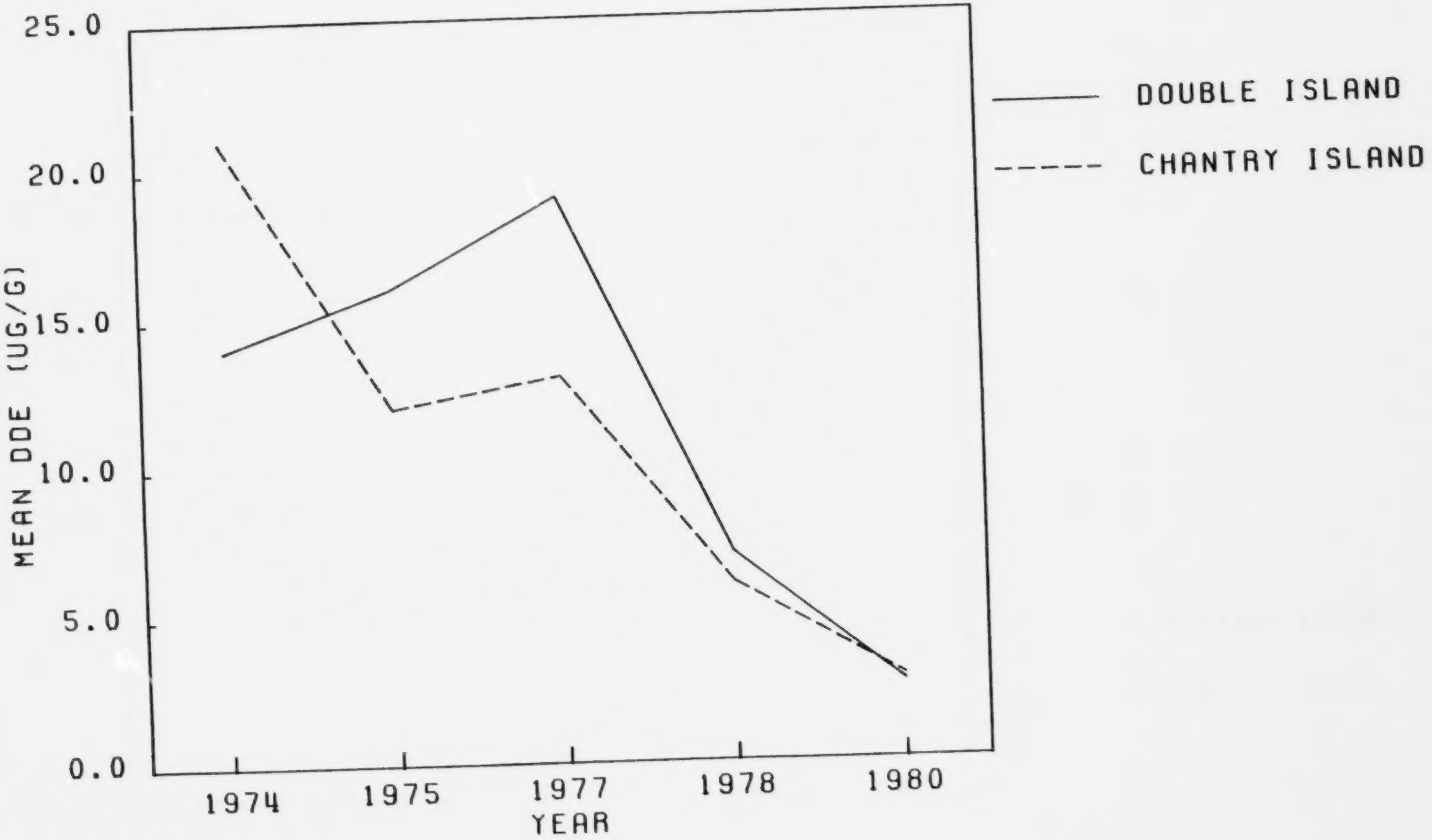

Figure 6-4. Mean DDE concentrations (µg/g) in herring gull eggs from Double and Chantry islands, Lake Huron, 1974-1980.

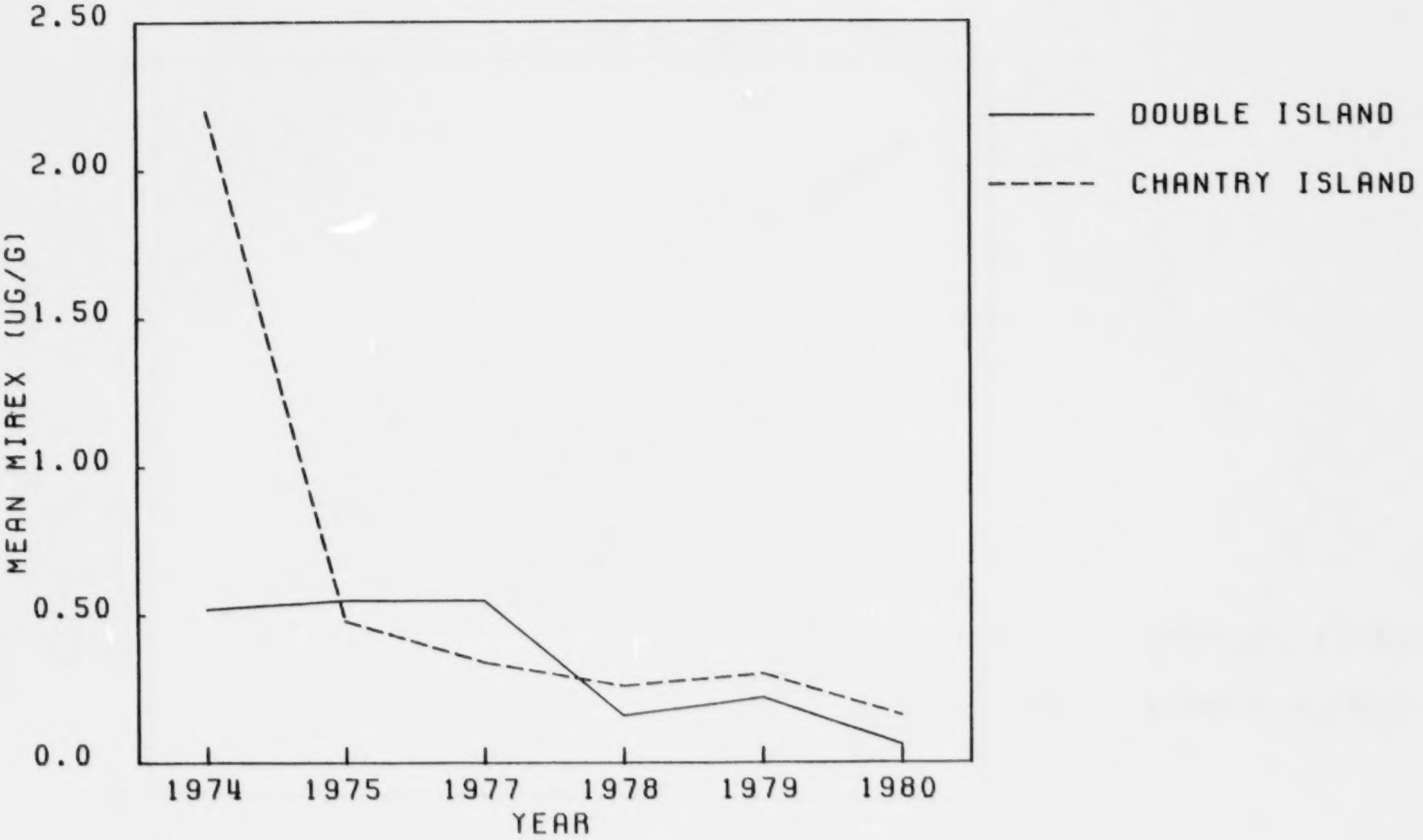

Figure 6-5. Mean Mirex concentrations (µg/g) in herring gull eggs from Double and Chantry islands, Lake Huron, 1974-1980.

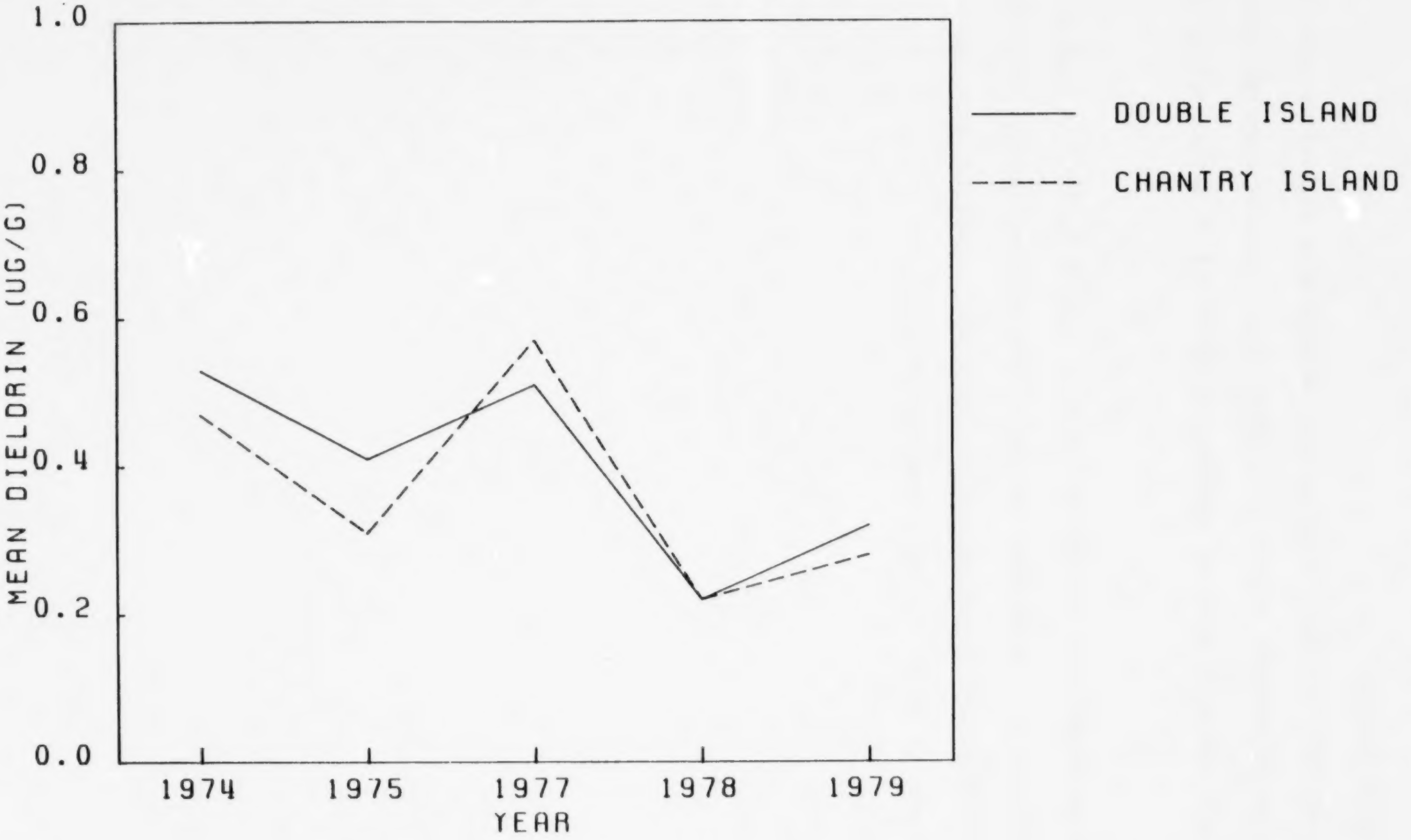

Figure 6-6. Mean dieldrin concentrations (µg/g) in herring gull eggs from Double and Chantry islands, Lake Huron, 1974-1980.

Heptachlor Epoxide

Heptachlor epoxide concentrations in eggs were highest in 1977 (Table 6-1) at Double and Chantry islands with lower concentrations reported subsequently. Regression analyses were not significant ($p < 0.05$) at either colony examined.

HCB

Hexachlorobenzene concentrations were highest in 1974 in eggs from both gull colonies with decreasing concentrations reported through 1979 (Table 6-1). Although declining trends are noted, log-linear regression analyses were not significant ($p < 0.05$) for eggs from either colony.

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CHAPTER SEVEN

ORGANIC CONTAMINANTS IN LAKE HURON SEDIMENTS

Studies on organic residues in Lake Huron sediments have been conducted between 1969 and 1977. Most sediment data are reports of PCBs and DDT-R contamination; however, some other organochlorine data are available. Mercury data are also included in this review and represent a sizeable data set. Although toxic materials are widespread in the sediments of Lake Huron, concentrations fall within the range of concentrations reported for the other Great Lakes (PLUARG 1978).

Sediments play a dual role in the fate of organic residues introduced to a lake system. The lake bottom ultimately serves as a permanent sink for organic contaminants; however, until complete burial has taken place, it often acts as a site of contaminant recycling. In areas with high sedimentation rates, organic residues may be permanently lost from the water column upon burial. Residue deposition may occur by sorption onto inorganic particles or from sorption to biotic materials which eventually die and settle to the bottom. Conversely, when organic residues are not buried or are located in shallow embayments (e.g., Saginaw Bay), they may be resuspended under certain limnological and meteorological conditions. Similarly, bioturbation within the sediments may allow residues to become available for entrainment into the water column.

Lake Huron organic contaminant and mercury distributions illustrate two major points. Firstly, organics and mercury may be found in high concentrations in nearshore zones indicating point sources of anthropogenic input. Secondly, they are generally found in high concentrations in the sediments of depositional zones as compared to non-depositional areas (Kemp and Thomas 1976). This observation may be the result of residues being associated with fine-grained sediments in combination with the physical characteristics of lake circulation. However, high concentrations in depositional areas may also be a result of their proximity to a point source.

Organic Contaminant Levels in Sediment

Mean organic residue concentrations detected in Lake Huron surficial sediment during the years 1969 through 1977 are presented by year, locality, and compound (Table 7-1). In order to inspect the spatial distribution of organic residues, in some cases, data are sub-divided for depositional basins, large nearshore segments, or specific nearshore localities. Using 1969 as an example, 174 samples were collected from the main portion of Lake Huron. These samples were separated into non-depositional (XD) and total depositional zones (BZ), with the number of samples presented in parentheses. Subsequently, the total depositional zones were further divided into individual depositional basins which are designated by code and have the number of samples presented in brackets. The names and locations of Lake Huron depositional basins (Fig. 7-1) are after Frank _et al_. (1979). The nearshore segmentation scheme, as developed by the Upper Lakes Reference Group (1977), is presented with their respective alphabetic designations (Fig. 7-2).

The International Joint Commission has not established concentration objectives for organic residues in sediments.

Table 7-1. Mean concentrations (ng/g) of organic residues detected in Lake Huron sediments, 1969-1977.

				PCB					DDT																
	n	Locality	Basin or Zone	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	Dieldrin	Aldrin	Endrin	Hepta-chlor	Hepta-chlor Epoxide	Chlordane	Endo-sulfan	Phenol	Hg	Source
1969	174	M		13.0					10.2	29.4		16.7		49.0	4.9	0.09	ND	ND	ND	0.07	ND	ND			1
	(97)		XD	11.0					3.8	31.6		15.6		52.6		0.2									1
	(77)		BZ	15.0					18.4	29.3		16.8		53.8		0.2									1
	[8]		MB	18.0					5.7	36.8		17.5		45.6		0.2									1
	[42]		MNB	12.0					17.9	32.4		14.0		53.6		0.2									1
	[5]		PHB	17.0					10.6	26.4		8.5		65.1		0.2									1
	[16]		GHB	19.0					31.1	22.5		23.2		54.3		0.2									1
	[2]		ALB	9.0					11.1	45.0		12.6		43.2		0.2									1
	[4]		SBB	33.0					12.2	37.7		14.8		48.4		0.2									1
	163	M																						222.0	2
	(89)		N																					171.0	2
	(74)		BZ																					283.0	2
	[11]		MB																					229.0	2
	[38]		MNB																					301.0	2
	[5]		PHB																					391.0	2
	[14]		GHB																					262.0	2
	197	M																						217.0	3
	(96)		XD																					166.0	3
	(80)		BZ																					277.0	3
	[11]		MB																					229.0	3
	[42]		MNB																					286.0	3
	[2]		ALB																					82.0	3
	[4]		SBB																					307.0	3
	[16]		GHB																					[illegible]51.0	3
	[5]		PHB																					438.0	3
1970	1																								4
	1																						110.0		4
		SB																						200.0	5

(Continued)

Table 7-1. Continued.

				PCB					DDT																
	n	Locality	Basin or Zone	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	Dieldrin	Aldrin	Endrin	Hepta-chlor	Hepta-chlor Epoxide	Chlordane	Endo-sulfan	Phenol	Hg	Source
1973	115	GB		13.0					5.8	43.1		27.6		27.6	1.7	0.21	ND	ND	ND	0.14	ND	0.15			1
	(75)		XD	11.0					3.4	41.2		29.4		29.4		0.2									1
	(93)		BZ	11.0					6.8	44.1		23.5		32.4		0.2									1
	[14]		NB	20.0					13.7	38.7		31.4		29.2		0.4									1
	[6]		OST	9.0					8.4	45.2		22.6		31.0		0.3									1
	[2]		LT	18.0					15.9	52.8		10.7		37.1		1.4									1
	[4]		CB	16.0					13.3	48.1		18.0		34.6		0.4									1
	[2]		FRB	24.0					7.3	32.9		11.0		57.5		0.4									1
	[7]		FPB	9.0					7.2	43.1		25.0		32.0		0.2									1
	55	MC		8.0					4.1	46.3		22.0		29.3	2.4	0.08	ND	ND	ND	0.15	ND	0.03			1
	171	GB																						222.0	3
	(76)		XD																					184.0	3
	(40)		BZ																					392.0	3
	[14]		NB																					301.0	3
	[6]		OST																					65.0	3
	[2]		LT																					4800.0	3
	[4]		CB																					72.0	3
	[7]		FPB																					75.0	3
	[3]		FRB																					79.0	3
	[1]		PSB																					200.0	3
	53	MC																						151.0	3

(Continued)

Table 7-1. Continued.

	n	Locality	Basin or Zone	PCB Total	PCB % 1260	PCB % 1254	PCB % 1248	PCB % 1242	DDT DDT-R	DDT % p,p'DDE	DDT % o,p'DDE	DDT % p,p'DDD	DDT % o,p'DDD	DDT % p,p'DDT	DDT % o,p'DDT	Dieldrin	Aldrin	Endrin	Hepta-chlor	Hepta-chlor Epoxide	Chlordane	Endo-sulfan	Phenol	Hg	Source
1974	3	SB	CV-N																					200.0	6
	3	M	HB-N																					200.0-300.0	6
	7	SB	SW-N																					100.0-300.0	6
	9	SB																						300.0-500.0	6
	9	M	PC-N																					200.0-300.0	6
	3	SB	PA-N																					200.0-300.0	6
	11								14.76	11.9		33.6		34.2	20.3	1.0									4
	13			12.0	25.0	50.0		25.0																	4
	1	SB		T					ND	ND		ND		ND	ND	ND	ND	ND	ND	ND	ND	ND			7
	2	NC		6.0					ND	ND		ND		ND	ND	ND	ND	ND	ND	ND	ND	ND			7
	5	GB		14.4					9.2	37.0		32.6		28.3	2.2	T	ND	ND	ND	ND	ND	ND			7
	8	M		4.0					3.9	60.9		0.00		35.5	0.00	T	ND	ND	ND	ND	ND	ND			7
		SB																						100.0	5

(Continued)

Table 7-1. Continued.

				PCB					DDT																
	n	Locality	Basin or Zone	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDD	% p,p'DDT	% o,p'DDT	Dieldrin	Aldrin	Endrin	Hepta-chlor	Hepta-chlor Epoxide	Chlordane	Endo-sulfan	Phenol	Hg	Source
1974-1975	8	M	A,B-N	65.0					ND	ND		ND		ND	ND	ND								<10.0	3
	6	M	C-N	ND					ND	ND		ND		ND	ND	ND								6.0-11.0	3
	12	GB	D-N	46.6					6.8	36.8		41.2		22.1	ND	1.6								5.0-64.0	3
	6	GB	E-N	40.0					T	T		ND		ND	ND	ND								<10.0-45.0	3
	19	NC	F-N	ND					21.5	16.3		20.0		31.2	32.6	ND								<10.0-149.0	3
	8	M	G-N																					<10.0	3
	6	SB	H-N																					<10.0	3
	5	M	I-N																					<10.0	3
	3	M	GH-N																					59.0	3
	3	GB	TB-N	40.0					8.0	50.0		ND		25.0	25.0	ND								51.0	3
	6	GB	OS-N	267.5					32.1	42.4		44.5		13.1	ND	ND								166.0	3
	3	GB	CW-N	853.0					27.3	30.0		51.3		18.3		ND								146.0	3
	18	GB	PM-N	32.0					7.2	30.6		69.4		T	ND	1.1								160.0	3
	20	GB	PS-N	ND					ND	ND		ND		ND	ND	ND								120.0	3
	19	NC	SP-N	56.8					5.1	27.5		37.3		35.3	ND	ND								55.0	3
	20	NC	ST-N	ND					1.3	100.0		ND		ND	ND	ND								77.0	3
	1	NC	DT-N																					<10.0	3
	5	M	CH-N																					<10.0	3
	19	M	SLH-O																					110.0	8
		NC	STM																				13000.0		3

(Continued)

Table 7-1. Concluded.

				PCB					DDT																
	n	Locality	Basin or Zone	Total	% 1260	% 1254	% 1248	% 1242	DDT-R	% p,p'DDE	% o,p'DDE	% p,p'DDD	% o,p'DDL	% p,p'DDT	% o,p'DDT	Dieldrin	Aldrin	Endrin	Hepta-chlor	Hepta-chlor Epoxide	Chlordane	Endo-sulfan	Phenol	Hg	Source
1975	3	M	CH-N																					100.0	6
		M	CL-N																					50.0	6
	1	SB		250.0	20.0	40.0		40.0	10.0	20.0		40.0		40.0		2.0									4
		SB																						120.0	5
1976	1	SB	PL-N						5000.0			20.0		40.0	40.0										4
		SB		1500.0- 2000.0																					9
		SB		69.8		39.0		61.0																	10
1976-1977	5	M	SR-N	ND					0.5							ND		ND		ND	0.2				11
1977		SB		4200.0- 182000.0																					12

LEGEND FOR TABLE 7-1.

1. Frank *et al.* (1979). PCBs measured against a standard of Aroclor 1254.
2. Thomas (1973). Top 3 cm.
3. Upper Lakes Reference Group (1977). Top 3 cm, nearshore.
   Top 5 cm, offshore.
4. Mich. Dept. Nat. Res. (1957-1978).
5. PLUARG (1977).
6. USEPA (1974).
7. Glooschenko *et al.* (1976). PCBs = sum of Aroclors 1242, 1254, and 1260.
8. Robbins (1980).
9. USEPA (1976).
10. Rice and Bowers (1981).
11. Ont. Min. Environment (1978).
12. Richardson *et al.* (1980).

KEY

1. Locality

M = main lake
GB = Georgian Bay
NC = North Channel
SB = Saginaw Bay

2a. Basin (see Figure 7-1)

XD = non-depositional zone
BZ = basin zones
MB = Mackinac basin
MNB = Manitoulin basin
PHB = Port Huron basin
GHB = Goderich basin
ALB = Alpena basin
SBB = Saginaw basin
N = nearshore
NB = Nottawasaga basin
OST = Owen Sound trough
LT = Lions trough
CB = Cabot basin
FRB = French River basin
FPB = Flowerpot basin
PSB = Parry Sound basin

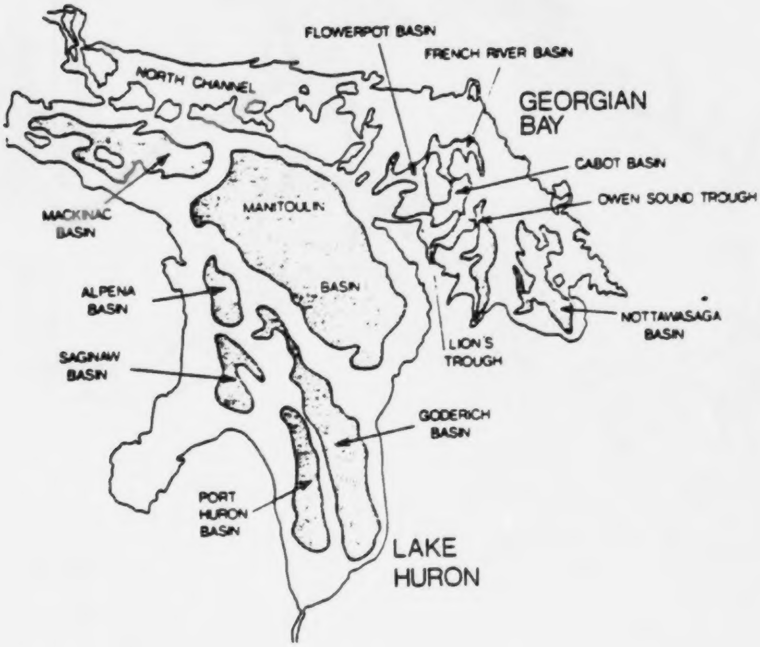
2b. Zone (see Figure 7-2)

CV-N = Caseville, Mi. - nearshore
HB-N = Harbor Beach, Mi. - nearshore
SW-N = Sebewaing, Mi. - nearshore
PC-N = Port Sanilac, Mi. - nearshore
PA-N = Port Austin, Mi. - nearshore
PL-N = Point Lookout Harbor, Mi. - nearshore
CL-N = Calcite Harbor, Mi. - nearshore
DT-N = DeTour, Mi. - nearshore
CH-N = Cheboygan, Mi. - nearshore
GH-N = Goderich, Ont. - nearshore
OS-N = Owen Sound, Ont. - nearshore
PS-N = Parry Sound, Ont. - nearshore
ST-N = Serpent River, Ont. - nearshore
SP-N = Spanish River, Ont. - nearshore
SR-N = Saugeen River, Ont. - nearshore
TB-N = Tobermory, Ont. - nearshore
CW-N = Collingwood, Ont. - nearshore
PM-N = Penetang-Midland, Ont. - nearshore
STM = Saint Marys River
SLH-O = Southern Lake Huron - offshore

IJC nearshore segments (see Figure 7-2)

A,B-N
C-N
D-N
E-N
F-N
G-N
H-N
I-N

ND = not detected
Blank = no data



FLOWERPOT BASIN
FRENCH RIVER BASIN
NORTH CHANNEL
GEORGIAN BAY
CABOT BASIN
OWEN SOUND TROUGH
MACKINAC BASIN
MANITOULIN
BASIN
ALPENA BASIN
NOTTAWASAGA BASIN
LION'S TROUGH
SAGINAW BASIN
GODERICH BASIN
PORT HURON BASIN
LAKE HURON

Figure 7-1. Lake Huron depositional basins (after Frank *et al*. 1979).

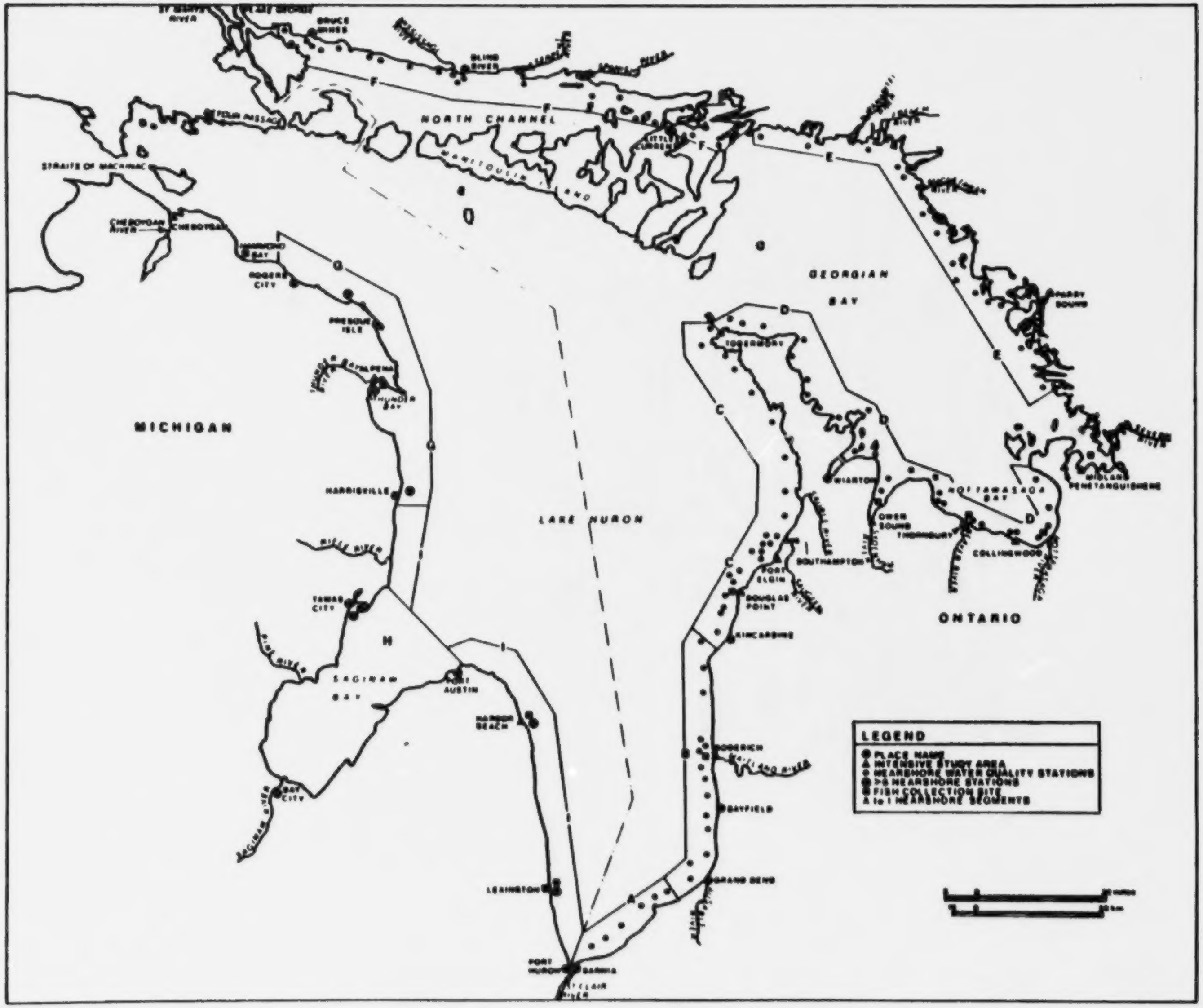

ST MARYS RIVER
BRUCE MINES
BLIND RIVER
SPANISH RIVER
NORTH CHANNEL
DETOUR PASSAGE
MANITOULIN ISLAND
LITTLE CURRENT
STRAITS OF MACKINAC
CHEBOYGAN RIVER
CHEBOYGAN
HAMMOND BAY
ROGERS CITY
PRESQUE ISLE
ALPENA
THUNDER BAY
THUNDER BAY RIVER
MICHIGAN
HARRISVILLE
RIFLE RIVER
TAWAS CITY
PINE RIVER
SAGINAW BAY
BAY CITY
SAGINAW RIVER
PORT AUSTIN
HARBOR BEACH
LEXINGTON
PORT HURON
SARNIA
ST CLAIR RIVER
LAKE HURON
GEORGIAN BAY
PARRY SOUND
FRENCH RIVER
TOBERMORY
WIARTON
OWEN SOUND
THORNBURY
NOTTAWASAGA BAY
COLLINGWOOD
MIDLAND
PENETANGUISHENE
SOUTHAMPTON
PORT ELGIN
DOUGLAS POINT
KINCARDINE
GODERICH
MAITLAND RIVER
BAYFIELD
GRAND BEND
ONTARIO
A
B
C
D
E
F
G
H
I
LEGEND
● PLACE NAME
▲ INTENSIVE STUDY AREA
● NEARSHORE WATER QUALITY STATIONS
● >5 NEARSHORE STATIONS
■ FISH COLLECTION SITE
A to I NEARSHORE SEGMENTS
miles
km

Figure 7-2. Nearshore segmentation scheme developed by the ULRG (1977) and locality orientation map.

PCBs

The highest PCB concentrations found in Lake Huron sediments are from Saginaw Bay (Table 7-1). The highest PCB concentrations were detected in 1977, ranging from 4,200.0 to 182,000.0 ng/g (Richardson et al. 1980). High concentrations were also reported for Saginaw Bay sediments in 1976 (USEPA 1976). These sediment samples were from the Saginaw River mouth extending out along the navigational channel and ranged from 1,500.0 to 2,000.0 ng/g (Table 7-1). Other high PCB concentrations in Saginaw Bay sediments were reported in 1975 at 250.0 ng/g (MDNR 1957-1978) and in 1976 at 69.8 ng/g (Rice and Bowers 1981).

For the major lake basins studied, Frank et al. (1979) found the highest concentrations of PCBs at 33.0 ng/g in 1969 collected in the Saginaw basin (SBB), which is in the main lake, but adjacent to Saginaw Bay.

For the main lake (M) and Georgian Bay (GB), Frank et al. (1979) found higher PCB concentrations in depositional areas (BZ) than in non-depositional (XD) zones (Table 7-1). Mean PCB concentrations for both the main lake and Georgian Bay were reported at 13.0 ng/g and a lower mean of 8.0 ng/g was reported for the North Channel (NC) (Table 7-1). In the main lake, the Saginaw basin showed the highest PCB concentrations, as previously discussed (Table 7-1). Other areas with high PCB concentrations were the Goderich basin (GHB), Mackinac basin (MB), and the Port Huron basin (PHB) which had concentrations of 19.0, 18.0, and 17.0 ng/g, respectively (Table 7-1). In Georgian Bay, the French River basin (FRB) and the Nottawasaga basin (NB) showed the highest PCB concentrations of 24.0 and 20.0 ng/g, respectively (Table 7-1). In a study by Glooschenko et al. (1976), Georgian Bay also showed comparatively high mean PCB concentrations at 14.4 ng/g. The North Channel followed by the main lake and Saginaw Bay showed lower concentrations at 6.0, 4.0 ng/g, and trace amounts, respectively, in this study (Table 7-1).

During 1974-1975, ULRG (1977) conducted a survey of PCB concentrations in the nearshore zones of Lake Huron. Of the lake segments analyzed, zones A and B (lower southeastern shore of Lake Huron) in the main lake showed the highest mean concentration of 65.0 ng/g (Table 7-1), but PCBs were only detected in two samples, one from near Bayfield and the other from the AuSable River mouth. Zone D, in Georgian Bay, had a concentration of 46.6 ng/g (Table 7-1). Specific nearshore sites in Georgian Bay were also sampled and high PCB concentrations were detected at Collingwood Harbour (CW-N) at 853.0 ng/g and in Owen Sound (OS-N) at 267.5 ng/g (Table 7-1).

DDT

The sum of DDT and its degradation products are presented (Table 7-1). From the most extensive studies on DDT residues, it appears that p,p'-DDT was the most abundant isomer in main Lake Huron. However, in Georgian Bay, p,p'-DDE or DDD were the most abundant isomers and p,p'-DDD was most abundant in the North Channel.

The highest DDT-R concentration reported for Lake Huron was 5,000.0 ng/g detected in the sediments at Point Lookout Harbor (PL-N) in Saginaw Bay (MDNR 1957-1978). All other reported DDT-R concentrations are considerably less, usually by two orders of magnitude.

Mean DDT-R concentrations in the main lake were higher than those recorded from Georgian Bay and the North Channel; 10.2, 5.8, and 4.1 ng/g, respectively. The highest mean DDT-R concentration in the main lake was reported for the Goderich basin at 31.1 ng/g (Table 7-1). The highest DDT-R concentration detected for depositional basins in Georgian Bay was recorded from Lions Trough (LT) at 15.9 ng/g (Table 7-1). In a study of DDT-R concentrations at nearshore areas, Owen Sound and Collingwood Harbour showed the highest concentrations at 32.1 and 27.3 ng/g, respectively.

Aldrin-Dieldrin

Aldrin was not detected in Lake Huron sediments (Table 7-1). The single highest dieldrin concentration was reported from Saginaw Bay at 2.0 ng/g in 1975 (MDNR 1957-1958). Georgian Bay exhibited a high mean dieldrin concentration of 0.21 ng/g followed by the main lake at 0.09 ng/g and the North Channel 0.08 ng/g (Table 7-1). Lions Trough in Georgian Bay had the highest dieldrin concentration of the major basins sampled at 1.4 ng/g (Table 7-1). In nearshore areas, segment D and Penetang-Midland, both in Georgian Bay, showed the highest dieldrin concentrations at 1.6 and 1.1 ng/g, respectively (Table 7-1).

Mercury

Mean mercury concentrations in the main lake and Georgian Bay were the same at 222.0 ng/g (Thomas 1973). North Channel mercury levels were considerably less with a mean concentration of 151.0 ng/g (Thomas 1973). Generally highest mercury concentrations were observed for depositional zones (Table 7-1). Of the major basins studied, Owen Sound Trough (OST) in Georgian Bay had the highest mercury concentration of 4,800.0 ng/g (ULRG 1977). In the main lake, the Port Huron basin showed the highest mean concentrations of 438.0 and 391.0 ng/g (Table 7-1).

Other Contaminants

Heptachlor epoxide was reported at concentrations of 0.15, 0.14, and 0.07 ng/g for the North Channel, Georgian Bay, and the main lake, respectively (Table 7-1). Chlordane was detected at the mouth of the Saugeen River in 1976-1977 at 0.2 ng/g (Table 7-1). Endosulfan was detected at 0.15 ng/g in Georgian Bay and at 0.03 ng/g in the North Channel but was not detected in the main lake (Table 7-1). Lindane was detected at 0.1 ng/g at the mouth of the Saugeen River in 1976-1977 (Ont. Min. Environ. 1978). Dibutyl phthalate was detected in sediments at the mouth of the Saginaw River at 290.0 ng/g and in outer Saginaw Bay at 200.0 ng/g (ULRG 1977).

Numerous other contaminants were sought but not detected in Lake Huron sediments. Endrin and heptachlor were not detected (LOD 1.0 ng/g) by Glooschenko *et al*. (1976). Methoxychlor was not detected (LOD 50.0 ng/g) by Glooschenko *et al*. (1976) nor by Frank *et al*. (1979). The Ontario Ministry of the Environment (1978) did not detect BHC at the mouth of the Saugeen River. Mirex was sought but not detected in Lake Huron sediments by Frank *et al*. (1979). Numerous organophosphorus pesticides were sought but not detected by Glooschenko *et al*. (1976). They included: phorate and disulfoton (LOD 10.0 ng/g); diazinon, ronnel, methyl parathian, malathion, parathion, ethion, dimenthoate, fenitrothion (LOD 20.0 ng/g); methyl trithion and carbophenothion (LOD 40.0 ng/g); crufomate and phosphamidon (LOD 100.0 ng/g); imidan, azinophosonethyl, and azinophosethyl (LOD 200.0 ng/g).

Results of Lake Huron Sediment Core Analysis

DDT-R and PCB concentrations in sediment cores (Table 7-2) were measured at several locations (Fig. 7-3). Core samples were analyzed to determine contaminant levels over time, whereas surficial sediments (discussed previously) were grab samples to determine the areal distribution of contaminants. In two cores from main Lake Huron, p,p'-DDT appeared to be the most abundant isomer and p,p'-DDE was the second-most abundant (Frank et al. 1979). DDT-R was not detected in these cores prior to 1947 which is equivalent to approximately 4 cm or lower in the core. PCB concentrations in cores from the main lake were highest at the surface; however, at station U-9, PCBs were detected at the 4-6-cm interval which corresponds to 1935.

Three cores were analyzed from Georgian Bay (Frank et al. 1979). The p,p' isomer of DDE appeared to be the most abundant DDT-R component followed by lower concentrations of p,p'-DDT (Table 7-2). At station C-7A, p,p'-DDE was found in the 1-10-cm interval of the core; however, the other two more finely sampled cores showed no DDT-R below the 2-cm interval prior to 1925. Similarly, PCBs were detected in the uppermost core intervals but were not present below the 2-cm level which corresponds to 1925.

A core from South Bay showed a high DDT-R value in the upper portion of the core where p,p'-DDE was the most abundant component (Frank et al. 1979). DDT-R was not detected below the 3-cm interval, dated at 1920.

PCBs were analyzed from sediment cores from southern Lake Huron and Saginaw Bay (Burin and Robbins 1977). The core from southern Lake Huron showed consistent PCB concentrations over time (Table 7-2). However, Saginaw Bay surface sediments showed much higher PCB concentrations compared to the pre-industrial era.

Table 7-2. Organic residues (ng/g) in dated Lake Huron cores.

Site (Year Collected)	Time Period	Depth (cm)	DDE	DDD	DDT	DDT-R	PCB	Source
Lake Huron								
DH (1971)	1943-1971	0-2	8.0	5.0	9.0	22.0	100.0	Frank et al. 1979
	1915-1942	2-4	ND	ND	ND	ND	ND	
	1829-1914	4-10	ND	ND	ND	ND	ND	
U-9 (1971)	1960-1971	0-2	3.0	2.0	3.0	8.0	30.0	
	1948-1959	2-4	4.0	ND	ND	4.0	10.0	
	1936-1947	4-6	ND	ND	ND	ND	10.0	
	1894-1935	6-10	ND	ND	ND	ND	ND	
Georgian Bay								
C-7A (1974)	1924-1974	0-1	14.0	6.0	8.0	28.0	20.0	Frank et al. 1979
	1424-1924	1-10	1.0-10.0	ND	ND	1.0-10.0	ND	
C-12A (1974)	1924-1974	0.1	8.0	2.0	7.0	17.0	9.0	
	1824-1923	1-3	ND	ND	ND	ND	ND	
J-3A (1974)	1950-1974	0-1	14.0	5.0	10.0	29.0	5.0	
	1925-1949	1-2	5.0	5.0	2.0	12.0	5.0	
	1725-1925	2-10	ND	ND	ND	ND	ND	
South Bay								
SB (1970)	1920-1970	0-3	18.0	9.0	9.0	36.0	20.0	Frank et al. 1979
	1808-1920	3-10	ND	ND	ND	ND	ND	
South Lake Huron								
(1977)	1947-1977	recent					20.0	Burin and Robbins 1977
	1747-1946	pre-industrial					20.0	
Saginaw Bay								
(1977)	1947-1977	recent					300.0	Burin and Robbins 1977
	1747-1946	pre-industrial					1.0	
	1947-1977	recent					1200.0	
	1747-1946	pre-industrial					1.0	

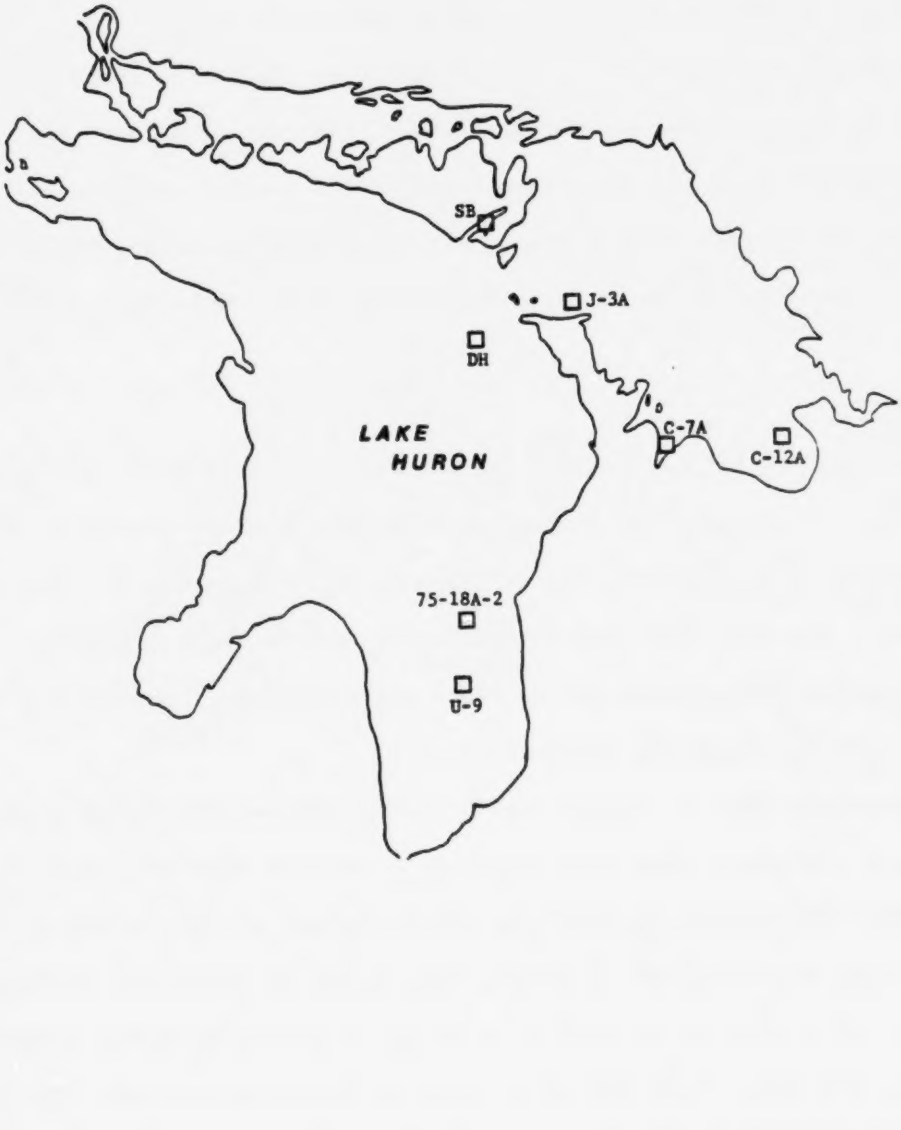

SB
J-3A
DH
LAKE
HURON
C-7A
C-12A
75-18A-2
U-9

Figure 7-3. Station locations and numbers for Lake Huron sediment core studies.

In general, highest DDT-R concentrations were observed in the upper portions of the cores from South Bay, Georgian Bay, and the main lake. Generally, DDT-R was not detected below 2 cm but never beyond 4 cm; these sediments were dated at 1947 and 1925, respectively. PCB concentrations were highest in the uppermost sediments of the Saginaw-Bay and main lake cores. The earliest appearance of PCBs in these cores was approximately 1925.

Mercury concentrations in Lake Huron cores (Table 7-3) were generally higher in the uppermost sediments; however, the core from South Bay (Kemp and Thomas 1976) showed the same concentrations for the 0-1 and 8-10-cm intervals. However, in the core from southern Lake Huron (Robbins 1980), there was a distinct reduction in mercury concentrations below the 10-cm interval.

Summary

The data on organic residue concentrations in Lake Huron surficial sediments are not suitable for addressing long-term trends. Generally, samples were taken too infrequently and at too many differing sites for this type of analysis. However, some general conclusions on the areal distribution of the major organic contaminants can be drawn and a historic framework can be established by inspecting sediment cores.

Generally highest organic residue concentrations were found in Saginaw Bay surficial sediments, with some nearshore localities also exhibiting high concentrations. When comparing main lake areas, highest concentrations of organics and mercury were detected in depositional basins as opposed to non-depositional basins. This observation appears to be due to the relationship found between residues and small-sized sediments found in depositional areas. The distributions of organics, in some cases, may reflect usage patterns.

Table 7-3. Mercury concentrations (ng/g) in Lake Huron cores.

Site/Station	Depth (cm)	Hg (ng/g)	Source
South Bay	0- 1	300.0	Kemp and Thomas 1976
1 (SB)	8-10	300.0	
Lake Huron	0- 2	130.0	
2 (DH)	8-10	80.0	
3 (U-9)	0- 2	200.0	
	20-30	70.0	
Southern Lake Huron SLH-75-18A-2	0- 1	145.0	Robbins 1980
	1- 3	140.0	
	3- 5	127.5	
	5-10	97.0	
	10-15	36.7	
	15-20	30.0	
	20-30	35.0	
	30-40	30.0	
	40-50	30.0	

Greatest PCB concentrations were found in Saginaw Bay surficial sediments, particularly during 1975 through 1977. As well, highest PCB concentrations found in the major basins of the main lake were in the Saginaw basin adjacent to Saginaw Bay, indicating that the bay is a source of PCB contamination. Lower PCB concentrations were found in other basins of the main lake, Georgian Bay, and the North Channel. In Georgian Bay, the French River basin showed the highest PCB concentrations. Nearshore studies at Collingwood Harbour and Owen Sound showed that sediments in these areas contained high PCB concentrations.

The highest DDT-R concentration was observed in Saginaw Bay. This high concentration, however, was suspect in that it was two orders of magnitude higher than any other report. DDT-R was found in high concentrations in the main lake, particularly in the Goderich basin. Lower concentrations were found in Georgian Bay and the North Channel. Differences were present in the component makeup of the DDT-R at these sites. In the main lake, p,p'-DDT was most abundant, whereas in Georgian Bay p,p'-DDE was most prevalent.

Mean dieldrin concentrations were high in Georgian Bay, particularly in Lions Trough and the nearshore zone at Owen Sound. Limited samples from Saginaw Bay also showed high concentrations. The main lake and the North Channel had lower dieldrin concentrations.

Mercury concentrations in the main lake and Georgian Bay exhibited the same mean concentration, with lower mercury concentrations in the sediments of the North Channel. In the main lake, the highest mercury concentration was observed in the Port Huron basin. In Georgian Bay, highest concentrations were seen at the Lions Trough. Nearshore studies failed to detect any obvious point sources.

Results of core studies analyzing for organic residues showed that DDT-R was generally not detected in sediments prior to 1925 or below the 2-4-cm interval at most localities. Similarly, PCBs in Georgian Bay and main Lake Huron were not found prior to 1925 or below 4-6 cm. In Saginaw Bay, PCB concentrations in recent sediments were much greater than those found in pre-industrial times. Similarly, mercury generally shows highest concentrations in recent sediments.

In most cases, finer interval data would have been more informative. Furthermore, sediments tend to retain an historic record of events which occur in the water column due to deposition in regular strata. Future analyses of fine interval core material may be a reliable method to determine trends for organic contaminants. Careful radiometric dating of the intervals would provide the necessary information for historic comparisons.

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CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

A wide array of contaminants has been detected in the lake basin and biota of Lake Huron. Approximately 70 contaminants have been identified to be present to date. The contaminants reported most frequently and in highest concentrations are PCBs, DDT-R, dieldrin, and mercury. Several other contaminants such as toxaphene, dioxin, PBB, and dibenzofurans are emerging environmental issues but have not been sufficiently studied. In general, Lake Huron contaminant concentrations fall within the range reported for the other Great Lakes. Within the data set, Saginaw Bay generally contains the highest concentrations of organic compounds in water, sediment, and biota and appears to be the region that should receive the greatest amount of concern and future study.

Limited data are available for atmospheric deposition of organic contaminants to Lake Huron. Most data are concerned with wet, dry, and bulk deposition of PCBs which were observed in highest concentrations of the contaminants sought. Highest PCB depositions were recorded for the last period of sampling from an offshore location in 1981. However, highest PCB loadings were generally recorded at Pinconning, Michigan. Measured PCB loadings show that dry deposition accounts for the largest proportion of PCB deposition to Lake Huron. Other contaminants detected in precipitation were alpha-BHC, methoxychlor, lindane, and polychlorinated terphenyls. PCB concentrations in snow samples roughly approximate concentrations observed for rainfall. PCB deposition to ice was also similar to concentrations detected in bulk PCB deposition.

Various organic compounds have been detected in Lake Huron water samples. Highest PCB concentrations were observed at Harbor Beach, Michigan. High concentrations were also reported in Saginaw Bay samples but at concentrations an order of magnitude less than at Harbor Beach. PCB concentrations in the offshore waters of Lake Huron, Georgian Bay, and the North Channel were considerably lower than the above sites. PCB concentrations at Harbor Beach and Saginaw Bay exceed the IJC objective of 1.0 ng/L. Water samples collected from Georgian Bay and the North Channel during 1980 slightly exceeded the IJC objective concentration of 1.0 ng/L; however, all 1981 samples from these regions were below the objective. All offshore Lake Huron water samples were substantially lower than the objective of 1.0 ng/L. DDT-R concentrations were highest in Saginaw Bay and Thunder Bay and exceeded the IJC objective concentration of 3.0 ng/L. DDT-R concentrations reported in open Lake Huron, Georgian Bay, and the North Channel in 1980 and 1981 were substantially below the IJC objective of 3.0 ng/L. During 1967, the St. Marys River contained the highest dieldrin concentrations reported for Lake Huron. All other reported concentrations since 1967 are below the IJC objective for dieldrin-aldrin of 1.0 ng/L. All reported concentrations of heptachlor-heptachlor epoxide, chlordane, lindane, and toxaphene are below the IJC objectives of 1.0 ng/L, 60.0 ng/L, 10.0 ng/L, and 8.0 ng/L, respectively. High concentrations of phenols have been detected in the St. Marys River; however, levels appear to be decreasing.

Diethylhexyl and dibutyl phthalate were detected in Lake Huron water samples. Dibutyl phthalate was in highest concentrations in the offshore waters of Lake Huron, with a lower concentration reported in Saginaw Bay. Both concentrations are below the IJC objective of 4,000.0 ng/L. Diethylhexyl phthalate was reported in Saginaw Bay water samples. Even though the most recent report showed lower concentration, all diethylhexyl phthalate concentrations are above the IJC objective of 600.0 ng/L. Other compounds that have been detected in

Lake Huron water samples are dimethyl sulfide, dimethoxymethane, chloroform, dimethyl disulfide, methyl palmitate, methyl stearate, terpene, camphor, simazine, atrazine, desethylatrazine, pentachlorobenzene, hexachlorobenzene, alpha BHC, and cyanide. Contaminants that have been sought but undetected are Mirex, endosulfan, p,p'-methoxychlor, and many organophosphorus compounds.

Very limited data are available for organic contaminants in net plankton and filamentous algae from Lake Huron (samples from 1974 and 1979 only), which indicates a need for further studies. PCBs, p,p'-DDE, and dieldrin were detected in the algae of Lake Huron. Numerous other organochlorine and organophosphorus compounds were sought but undetected. Of the three contaminants found in algae, PCBs exhibited the highest concentrations. Highest concentrations of PCBs were found in the plankton of southern Lake Huron and Georgian Bay. Comparatively much lower PCB concentrations were observed in filamentous algae than in plankton. *Ulothrix* contained slightly higher PCB concentrations than *Cladophora*. In all PCB analyses of algal collections, Aroclor 1242 was the most important component. *Cladophora* contained the highest concentrations of p,p'-DDE. Other algal samples showed either very low or undetected p,p'-DDE concentrations. Dieldrin was observed in trace concentrations in the plankton.

Numerous organic compounds have been detected in Lake Huron fish tissue. Because of their widespread occurrence, PCBs should clearly receive priority concern; however, other newly discovered toxic substances need special attention as well, because sufficient data are presently unavailable. Recent analyses of Lake Huron fish indicated that PCBs are relatively high, and Saginaw Bay fish had higher PCB concentrations than fish from any other region in Lake Huron. Analysis of long-term trends in individual species did not show significant increases in PCBs; however, species such as common carp showed increasing concentrations from 1978 through 1980. Fish from the main lake showed comparatively lower concentrations than Saginaw Bay fish or nearshore fish in general. All major commercial and game fish collected in 1980, excepting smelt, exceeded the IJC objective of 0.1 mg/kg. Also, common carp, channel catfish, yellow perch, lake trout, bloater, lake whitefish, walleye, coho salmon, chinook salmon, brown trout, splake, rainbow trout, cisco, burbot, and northern pike exceeded the IJC objective during the last year these species were analyzed for PCBs.

Analysis of DDT-R concentrations in Lake Huron fish indicates considerably lower concentrations in recent years. No specific lake region was identified as having higher DDT-R concentrations than any other region. Only three Lake Huron fish species (bloater, splake, and burbot) contained DDT-R concentrations exceeding the IJC objective of 1.0 mg/kg during the last year these species were analyzed for DDT-R.

Dieldrin concentrations in Lake Huron fish appear to be uniform over the time period 1967 to 1980. Generally, dieldrin concentrations were higher in main lake and Alpena, Michigan, fish than in fish captured in Saginaw Bay and other areas of the lake. Only two species, yellow perch and splake, contained concentrations in excess of the IJC objective concentration of 0.3 mg/kg during the last period of sampling for these species.

Analysis of mercury concentrations in all Lake Huron fish indicated that the highest mercury concentrations have been reported since 1975. Only walleye were above the IJC objective concentration of 0.5 mg/kg for mercury. Generally, walleye collected in northern Lake Huron and Georgian Bay had the highest mercury concentrations.

All Lake Huron fish are below the objective of 0.3 mg/kg proposed by the IJC for lindane, endrin, and heptachlor-heptachlor epoxide.

Newly discovered organic compounds in Lake Huron fish are toxaphene, dioxin, PBB, and dibenzofuran. The highest concentration of toxaphene (9.00 mg/kg) was found in lake trout from Alpena, Michigan, in 1977. This constitutes the highest toxaphene concentration reported for any fish species in the Great Lakes. Dioxin residues were first detected in fish from Saginaw Bay in 1978. Dioxin has been reported in four species from Saginaw Bay, with concentrations as high as 153.0 ng/kg. PBB (polybrominated biphenyl) was reported in yellow perch and channel catfish from Saginaw Bay in 1978 at concentrations as high as 21.0 μg/kg. Dibenzofuran residues were detected in carp and lake trout in 1979, with concentrations to 32.0 ng/kg.

Numerous other compounds that have not had IJC objective concentrations established have been detected in various Lake Huron fish species. The major compounds are cis- and trans-chlordane, cis- and trans-nonachlor, oxychlordane, methoxychlor, hexachlorobenzene, alpha-BHC, trichlorobenzene, tetrachlorobenzene, pentachlorobenzene, naphthalene, phenanthrene, dibutyl phthalate, diethyl phthalate, di-2-ethylhexylphthalate, methyl mercury, and octachlorostyrene. Major compounds that have been sought but not detected in Lake Huron fish are Mirex, dacthal, and 3-trifluoro-methyl-4-nitrophenol.

Several needs for conducting monitoring programs and fish analyses are apparent from inspecting the data set of Lake Huron fish contaminants. We recommend that monitoring should be conducted yearly at consistent sites. The same species should be sampled yearly at an individual site for internal consistency, recognizing that the same species may not occur from locality to locality. We recommend that salmonids be collected yearly during fall runs and monitored at several sites for comparative purposes. Concurrently, a program should be initiated to collect species specifically inhabiting the waters in the offshore zone. More attention should be given to collecting and reporting analyses of different size, sex, and age classes. Fish analyses should be made on edible fish portions because of the overriding importance to human health. Analyses of organics should be conducted using both electron-capture gas chromatography and mass spectrometry.

Organic residues have been detected in herring gull eggs at nine gull colonies in Lake Huron. Of the organic contaminants observed in herring gull eggs, PCBs were detected in highest concentrations. From 1980 data, PCB concentrations in herring gull eggs at colonies in Saginaw Bay were 2-4 times higher than eggs at other colonies, with the exception of the colony at Manitoba Reef. Similarly, 1980 dioxin concentrations were 3-6 times greater in herring gull eggs at colonies in Saginaw Bay than outside of the bay. DDE was the most abundant DDT-R component found in herring gull eggs. Data for short-term trend analysis, between 1974 and 1980, were available for eggs at Double and Chantry islands only. Analysis indicated significant decreases in PCB and mirex concentrations in herring gull eggs at both Double and Chantry islands. Significant decreases were also seen in DDT concentrations in eggs at Double Island and DDE concentrations in eggs at Chantry Island. Although declining concentrations of dieldrin, heptachlor epoxide, and hexachlorobenzene were observed for eggs at both colonies, statistically significant decreases were not indicated. Other contaminants detected in herring gull eggs at Double and Chantry islands were photomirex, oxychlordane, BHC, 1,2,3,4 tetrachlorobenzene, pentachlorobenzene, mercury, and lead. Dibenzofuran was detected in herring gull muscle at

Channel/Shelter Island in Saginaw Bay. The compound 1,2,4,5 tetrachlorobenzene was not detected in herring gull eggs.

Highest concentrations of organic contaminants in Lake Huron sediments were found either in nearshore zones or in depositional basins. The sediments of Saginaw Bay contained the highest PCB concentrations recorded. Consequently, the Saginaw basin, adjacent to Saginaw Bay, had the highest PCB concentrations of the major depositional basins sampled. Other depositional basins in the main lake, Georgian Bay, and the North Channel contained comparatively lower PCB concentrations than the Saginaw basin. Nearshore areas at Collingwood Harbour and Owen Sound in Georgian Bay exhibited the highest PCB concentrations detected for the nearshore zones; however, concentrations were considerably less than in Saginaw Bay. The highest DDT-R concentration in sediments was observed in Saginaw Bay at Point Lookout Harbor. Of the major basins sampled, the Goderich basin in the southern portion of the lake had the highest concentrations. Much lower concentrations were observed in other basins of the main lake, Georgian Bay, and North Channel. Nearshore studies showed highest DDT-R concentrations at Owen Sound and Collingwood Harbour in Georgian Bay; however, concentrations were two orders of magnitude lower than those reported for Saginaw Bay. The single highest dieldrin concentration was observed in Saginaw Bay. Lions Trough in Georgian Bay and nearshore segment D in Georgian Bay showed the next highest concentrations. The highest mercury concentration recorded was for the Owen Sound Trough in Georgian Bay. Much lower mercury concentrations were observed at the Port Huron basin in the southern portion of the lake. Nearshore studies did not reveal point sources. Other contaminants detected in the sediment of Lake Huron were heptachlor epoxide, chlordane, endosulfan, lindane, and dibutyl phthalate. Endrin, heptachlor, methoxychlor, alpha-BHC, Mirex, and numerous organophosphorus pesticides were sought but not detected. Results of core analyses from Lake Huron indicate that DDT-R and PCB were usually not detected in sediments dated prior to 1925, or deeper than 4 cm in the sediment record. Results also indicate that PCB concentrations in the sediments of Saginaw Bay are much higher in recent years compared to pre-industrial times. From the most finely sampled core study on mercury, there is a distinct decrease in mercury concentrations below 10 cm.

Inspection of the data set on organic contaminants in Lake Huron indicates several points. Monitoring and surveillance studies should be continued for all biotic and lake basin elements. Surveillance should be conducted yearly at constant sites so that trends can be identified and comparisons can be made from site to site.

Additional monitoring studies of different biotic elements in the Lake Huron food chain should be initiated. Probably one of the most deficient areas of organic contaminant sampling is for invertebrates, which constitute a large portion of the diet of certain fish species. Invertebrates such as annelids, crustacea, insects, and molluscs have not been analyzed for contaminants in Lake Huron and should have surveillance programs initiated. Certain of these groups have been studied in Lake Ontario (Shear 1981) and Lake Michigan (Evans et al. 1982). Another group to be inspected may be amphibians. Vertebrate groups have not been sampled for organic compounds, probably due to cost inefficiency. However, muskrat, beaver, deer, and even bear could be sampled for organic concentrations. Studies investigating the effect of PCBs on commercially reared mink have been conducted. Experimental work on PCBs has shown that mink suffer high mortality rates and reproductive complications when fed Great Lakes fish (Aulerich and Ringer 1977).

Lastly, we believe that the major objective, to compile the available contaminant data for Lake Huron, has been accomplished. We recommend that these records should be updated every five years, adding the results of newly-conducted surveys and overlooked previous studies, and emerging environmental problems should be sought. Analysis of long-term trends presented in this study should be considered preliminary, primarily due to the overwhelming time constraints of data compilation. However, we recommend that these data, upon the next update, be computerized. This would afford easier extraction of certain types of data and more efficient sorting by region, contaminant, age, weight, species, etc. In the same vein, a computerized data base would allow a more effective data management scheme for data analysis.

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APPENDIX

June 23, 1982

ORGANOCHLORINES IN OFFSHORE WATERS OF LAKE HURON, NORTH CHANNEL AND GEORGIAN BAY, 1980 AND 1981

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Summary

Organochlorine toxins were measured in large water samples (~100ℓ) collected at 18 offshore stations in Lake Huron, Georgian Bay and North Channel during two cruises of the R/V Roger Simons, July 14-28, 1980 and May 13-17, 1981 (Figure 1). Methylene chloride extracts of whole water prepared aboard ship were analyzed for polychlorinated biphenyls (PCBs), pentachlorobenzene, hexachlorobenzene, 4,4'-DDT and 4,4'-DDE using high-resolution capillary gas chromatography. Concentrations of PCBs ranged from 0.1-3.2 ng/ℓ. The other organochlorine concentrations were measured at levels below 0.1 ng/ℓ.

Methods

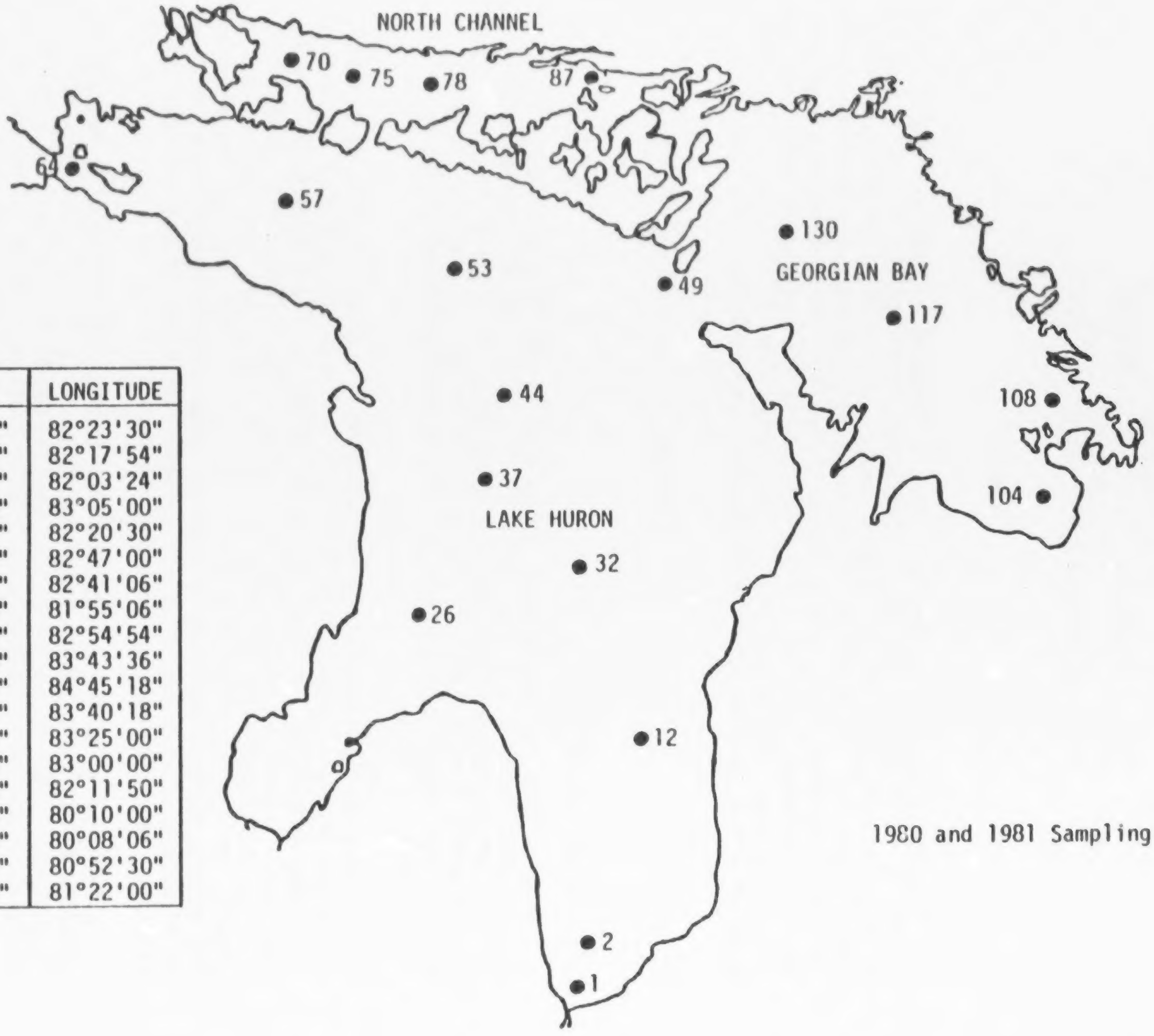
Sampling and Extractions

Samples from 4 m depths were pumped aboard the R/V Roger Simons at a rate of ~10ℓ/min using a 2 cm (ID) Tygon® (PVC) hose and high speed impeller pump. Part of the sample stream was diverted at the rate of ~2ℓ/min throug approximately 4 m of 9 mm (ID) Teflon® tubing using a peristaltic pump with silicon rubber pump tubing. All hoses were purged with station water before sampling began.

At most stations 96ℓ (1980) or 120ℓ (1981) samples of whole water were collected in 1-gal. amber glass jugs with Teflon®-lined caps. These were obtained, precleaned for pesticide grade solvents, from Burdick & Jackson Labs (B&J). Each jug containing 3ℓ of water sample was spiked immediately with 200 mℓ of methylene chloride (pesticide grade, B&J) and shaken vigorously for 3 min. After standing for 2 hours or more at room temperature, the solvent layers were removed from all jugs. Each jug was rinsed with 50 mℓ of methylene chloride which was subsequently added to the combined sample extract. New sampling jugs were used at each station.

After several months of storage (dark, room temperature) the methylene chloride extract was transferred in portions to a 500 mℓ separatory funnel. The solvent layer and water-solvent emulsion were drained through a column of pre-cleaned anhydrous sodium sulfate with glass wool plugs at the top and bottom. Three 50 mℓ methylene chloride rinses of each jug were also passed through the separatory funnel and column, and combined with the main extract. This clear extract was then concentrated in several stages to 25 mℓ by

Figure 1


NORTH CHANNEL
70
75
78
87
64
57
53
49
130
GEORGIAN BAY
117
44
108
37
104
LAKE HURON
32
26
12
2
1

STA.#	LATITUDE	LONGITUDE
1	43°05'24"	82°23'30"
2	43°11'24"	82°17'54"
12	43°53'24"	82°03'24"
26	44°20'00"	83°05'00"
32	44°27'12"	82°20'30"
37	44°45'42"	82°47'00"
44	45°01'00"	82°41'06"
49	45°24'48"	81°55'06"
53	45°27'00"	82°54'54"
57	45°40'00"	83°43'36"
64	45°48'48"	84°45'18"
70	46°08'12"	83°40'18"
75	46°05'00"	83°25'00"
78	46°02'06"	83°00'00"
87	46°03'40"	82°11'50"
104	44°38'45"	80°10'00"
108	44°57'10"	80°08'06"
117	45°14'42"	80°52'30"
130	45°32'30"	81°22'00"

1980 and 1981 Sampling Stations

boiling over a steam bath in a single 500 mℓ Kuderna Danish (KD) flask fitted with a Snyder column and 10 mℓ lower tube. A 250 mℓ volume of N-hexane was passed through the same separatory funnel and sodium sulfate column was added to the 25 mℓ of sample extract in the KD flask. The extract in the KD flask was then concentrated over steam to ∿ 10 mℓ. The hexane volume was further reduced to 2 mℓ under a nitrogen stream in a graduated tube placed in a warm water bath.

Cleanup

The final extract (2 mℓ in hexane) was partially cleaned of lipids by mixing it in a stoppered glass tube with concentrated sulfuric acid and allowing it to stand overnight. After the acid layer was frozen in a bath of acetone-dry ice the hexane layer was removed by pipet and transferred to a column of 5 g of 70/230 mesh Silica Gel 60 (E. Merck). Two fractions were collected during elutions with 80 mℓ of 2% benzene in hexane and 40 mℓ of 25 diethyl ether in hexane. Both fraction volumes were reduced again to 2 mℓ in hexane and recleaned with sulfuric acid before analysis by gas chromatography (GC).

Analysis and Quantitation

Analysis was conducted with a Varian 3700 high-resolution, capillary gas chromatograph (GC) fitted with dual Ni^{63} electron capture detectors, auto samplers and 50 m SE-54 fused silica columns. Chromatographic conditions were as follows: injector temperature, 270°C; column temperature programmed at 1°C/min from 100-260°C holding the final temperature for 10 minutes; detector temperature, 320°C. Hydrogen was the carrier gas at a linear velocity of 0.5 m/sec, and nitrogen was the detector makeup gas at a flow rate of 30 mℓ/min.

Values for total PCBs were calculated by summing the concentrations of component isomers, which were identified within a standard PCB mixture by coelution with synthetic PCB isomers. To date 180 isomer standards (of a possible 209) have been characterized by capillary GC. The standard mixture used is a combination of Aroclors 1016, 1254 and 1260. For samples, the capillary PCB totals tend to be lower than in packed column analysis probably because with capillary analysis the PCB peaks are better resolved and less contaminated with other substances.

Other organochlorines (4,4'-DDE, 4,4'-DDT, hexa- and pentachlorobenzene) were quantified using a standard mixture composed of known concentrations of each. The response factor of each component in the standard was multiplied by the peak area for each compound in the sample to yield a concentration value.

Quality Control and Quality Assurance

All glassware coming in contact with samples was cleaned with soap and water, baked at 490°C overnight and then washed three times each with methylene chloride, acetone and hexane. All glassware blanks were run on the capillary GC and glassware was recleaned when necessary until no interferin contamination was observed.

GC analysis of nine glassware sets was required for each sample extracted, concentrated and run through silica gel separation. Four glasswar sets were used for standards run through silica gel separation to determine percent recovery.

Each set of five environmental samples plus associated standards for QA (quality assurance) required capillary GC analysis of 90 glassware blanks, representing 270 hours of GC running time. Each five samples plus associated standards required 38 capillary GC runs which represented 109 hours of run time. With three capillary columns for glassware analyses and two capillary columns for actual sample set analyses, a total analysis time of 145 hours was required.

GC Time Allocations for Set of Five Environmental Samples

	# Hours	% of Total Run Time
Std.	34	9.0
Glassware	270	71.2
QC/QA	45	11.9
Sample	30	7.9
Total	379	100.0

Two types of blanks were used to assess contamination of samples during preparation for analysis. The first solvent blanks in Table 1 was processed as a sample and represented the same volume of solvent used to extract the sample. A second type of blank was used to measure the contamination caused by the silica gel separation columns. A volume of solvent equal to that used in separating a sample extract on silica gel was passed through the column and processed in the same manner as the sample extract. For PCBs, pentachlorobenzene, 4,4'-DDE and 4,4'-DDT, the silica gel column contributed 40 percent or more of the contamination seen. For hexachlorobenzene the silica gel did not appear to be a source of contamination.

To insure further quality control and quality assurance an EPA QC Aroclor 1254 standard was run with each set of five samples to monitor and insure accuracy, as well as to determine between-run precision of PCB quantitation.

Percent recoveries of standards from silica gel separation columns for each of the organochlorines measured were determined for each set of five samples, Table 1. The values of percent recovery ranged from 88.3 to 182.9.

Table 1. Summary of Sample and Quality Control Data.

Station	Vol. L	Organochlorine Levels ng/L					% Recovery of Standard From Silica Gel Separation Column					% Blank Is Of Sample				
		PCB	Pentachlorobenzene	Hexachlorobenzene	4,4'-DDE	4,4'-DDT	PCB	Pentachlorobenzene	Hexachlorobenzene	4,4'-DDE	4,4'-DDT	PCB	Pentachlorobenzene	Hexachlorobenzene	4,4'-DDE	4,4'-DDT
02	90	.385	.006	.005	.010	.014	NA	78.95	77.9	130	108	42.3	19.2	12.7	55.3	58.3
32	96	.456	-	.017	.018	.035	NA	78.95	77.9	130	108	31.0	-	7.9	26.9	19.2
57	93	.282	.004	.004	.010	.010	NA	78.95	77.9	130	108	48.1	24.8	33.3	46.5	61.6
78	96	.766	.006	.012	.056	.042	NA	78.95	77.9	130	108	24.0	22.6	30.3	11.3	21.5
117	96	.572	.003	.005	.021	.020	NA	78.95	77.9	130	108	24.8	38.3	28.7	19.1	37.1
01*	120	.349	.003	.007	.018	.027	71	100.5	100.8	116.2	182.9	37.6	22.4	6.1	19.1	11.5
130*	120	.135	.001	.002	.006	.007	71	100.5	100.8	116.2	182.9	81.5	44.0	20.7	53.6	43.9
75*	120	.205	-	.004	.010	.018	71	100.5	100.8	116.2	182.9	53.8	-	11.6	33.3	18.2
26*	120	.532	.002	.004	.012	.009	71	100.5	100.8	116.2	182.9	20.7	33.3	10.0	28.7	32.8
53*	120	.780	.002	.006	.012	.010	71	100.5	100.8	116.2	182.9	29.0	29.1	7.2	27.4	26.3
37	96	.465	.006	.007	.012	.028	99	88.3	90.5	112.0	105.9	28.7	15.1	10.9	37.3	18.4
53	96	.673	.004	.006	.019	.029	99	88.3	90.5	112.0	105.9	32.8	38.7	21.8	41.1	29.8
130	96	1.805	.007	.019	.056	.036	99	88.3	90.5	112.0	105.9	16.3	29.9	9.4	17.9	31.3
49	96	.384	.003	.003	.023	.030	99	88.3	90.5	112.0	105.9	46.2	40.3	33.8	25.3	22.5
12	96	.331	.003	.004	.011	.017	99	88.3	90.5	112.0	105.9	38.2	27.4	17.8	40.6	29.5
87	96	3.232	.007	.017	.090	.062	106.8	112.6	109.6	122.7	121.6	5.8	9.9	6.2	7.0	21.2
104	96	2.341	.005	.015	.067	.042	106.8	112.6	109.6	122.7	121.6	6.5	24.4	5.5	7.5	25.2
70	96	1.172	.003	.008	.038	.029	106.8	112.6	109.6	122.7	121.6	9.2	26.5	7.2	9.4	25.8
108	96	.707	.003	.007	.021	.015	106.8	112.6	109.6	122.7	121.6	21.4	47.4	12.6	23.8	70.9
64	96	.368	.003	.003	.015	.017	106.8	112.6	109.6	122.7	121.6	45.5	49.3	29.0	34.0	61.1

*Samples collected in 1981.

Results

The organochlorine values measured for each of the twenty samples, the percent recovery of standards from silica gel separation columns and the percentage the blank was of the sample are shown in Table 1. In 1981, three samples were collected in Lake Huron and one each from the North Channel and Georgian Bay.

PCB (Figure 2)

The levels of PCB ranged from .135 ng/ℓ at Station 130 (1981) in Georgian Bay to 3.232 ng/ℓ at Station 87 (1980) in the North Channel. The mean values for 1980 data were: Lake Huron .418 ng/ℓ, North Channel 1.723 ng/ℓ and Georgian Bay 1.356 ng/ℓ. The mean value for 1981 Lake Huron data was .553 ng/ℓ.

Pentachlorobenzene (Figure 3)

Station 130 (1981) Georgian Bay showed the lowest level at .001 ng/ℓ while the highest level was measured at Station 87 (1980) in the North Channel. Mean values based on 1980 data were: Lake Huron .004 ng/ℓ, North Channel .005 ng/ℓ and Georgian Bay .004 ng/ℓ. The 1981 mean value for Lake Huron was .002 ng/ℓ.

Hexachlorobenzene (Figure 4)

Levels ranged from .002 ng/ℓ at Station 130 (1981) Georgian Bay to .019 ng/ℓ measured at Station 130 (1980) Georgian Bay. Mean values calculated from 1980 data showed Lake Huron at .006 ng/ℓ, North Channel at .012 ng/ℓ and Georgian Bay with .011 ng/ℓ. The Lake Huron 1981 mean value was .007 ng/ℓ,

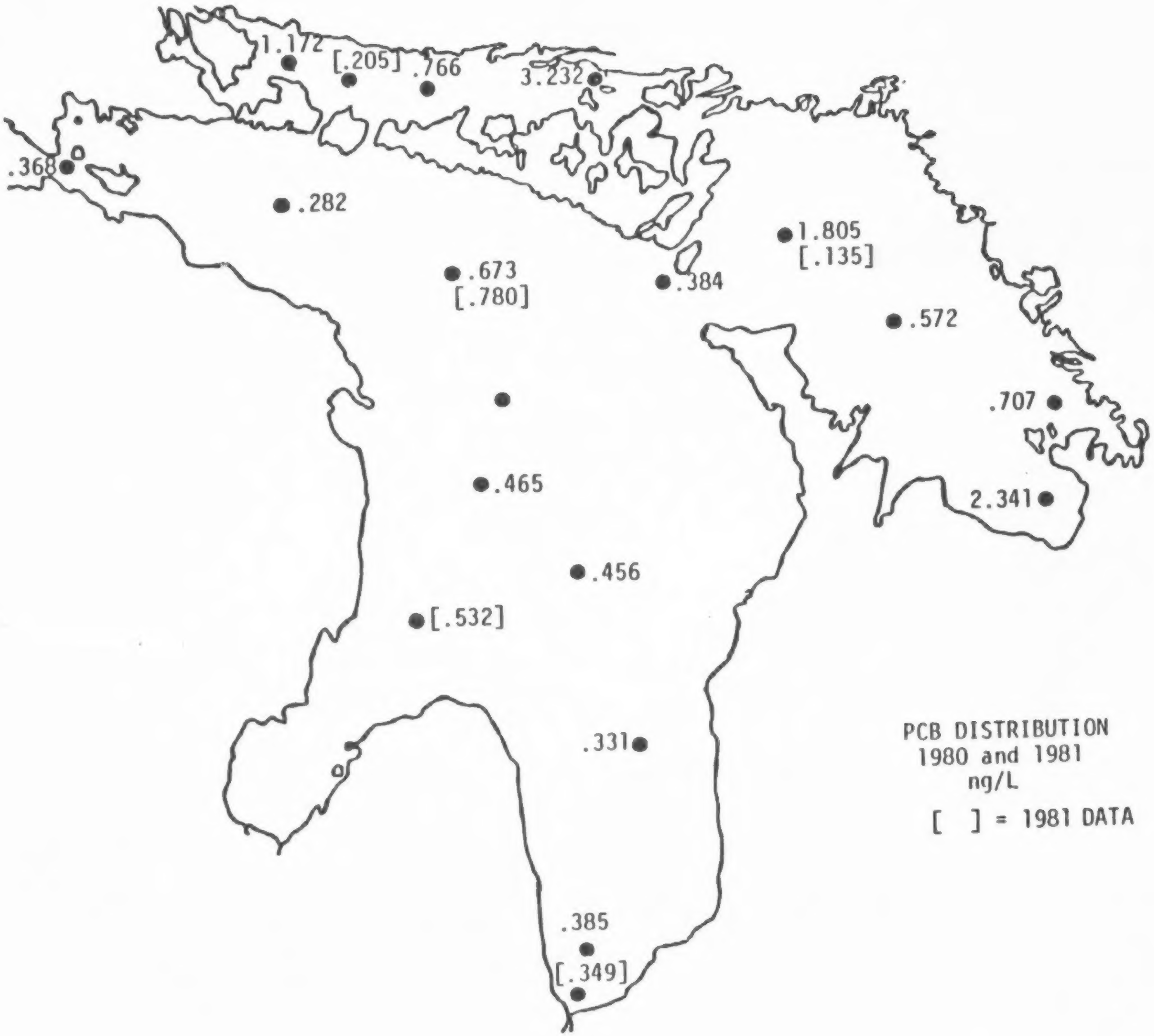
4,4'-DDE (Figure 5)

4,4'-DDE ranged in levels from .002 ng/ℓ at Station 130 (1981) Georgian Bay to .019 ng/ℓ Station 87 (1980) North Channel. The 1980 data showed Lake Huron with a mean of .015 ng/ℓ, North Channel .061 ng/ℓ and Georgian Bay .043 ng/ℓ. The mean value established for Lake Huron 1981 was .014 ng/ℓ.

4,4'-DDT (Figure 6)

Samples from Station 130 (1981) in Georgian Bay showed the lowest levels of 4,4'-DDT at .007 ng/ℓ while Station 104 (1980) Georgian Bay showed the highest level .067 ng/ℓ. The mean values of 1980 data were: Lake Huron .023 ng/ℓ, North Channel .044 ng/ℓ and Georgian Bay .028 ng/ℓ. The 1981 Lake Huron mean was .015 ng/ℓ.

Figure 2



PCB DISTRIBUTION
1980 and 1981
ng/L
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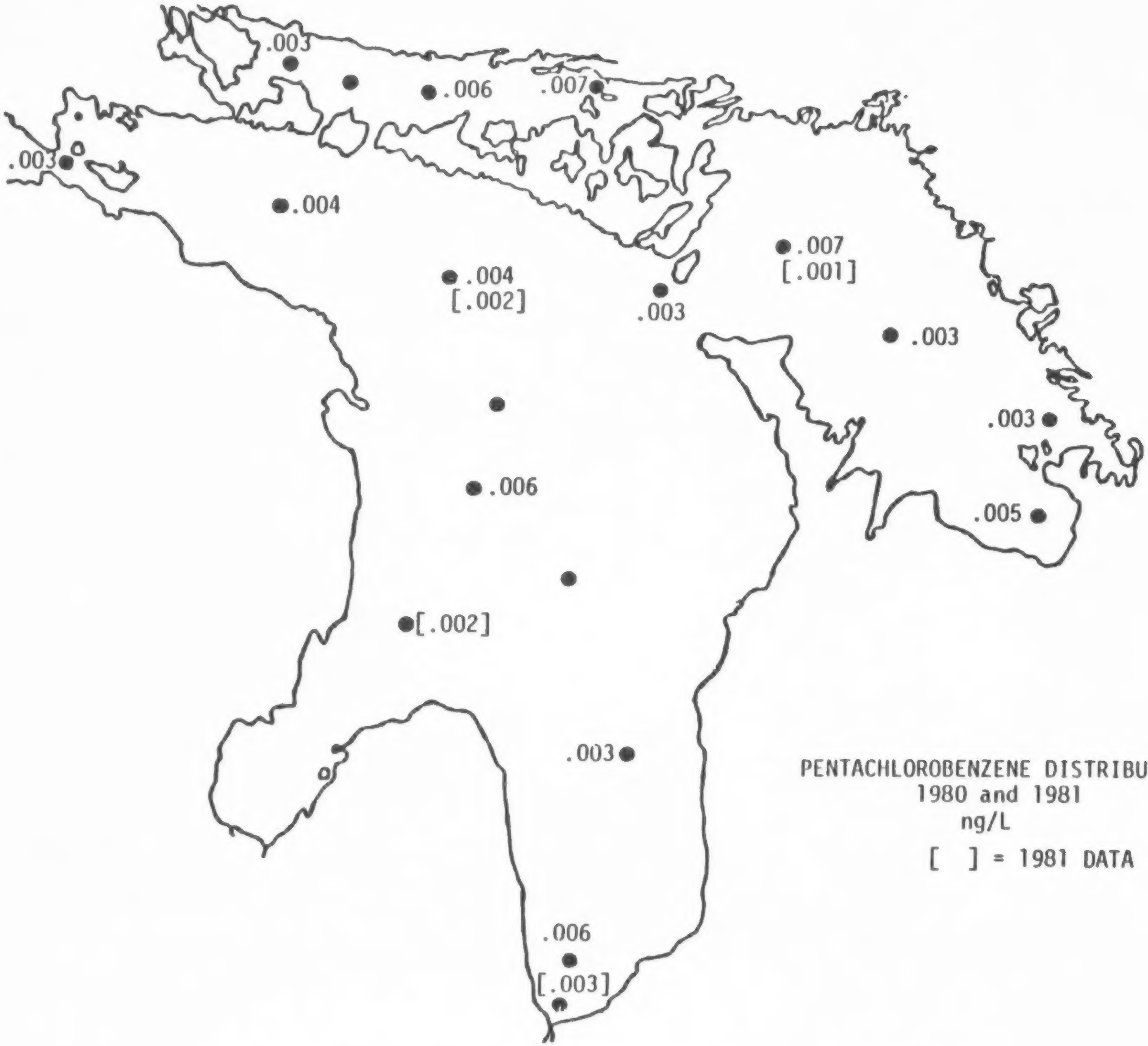
Figure 3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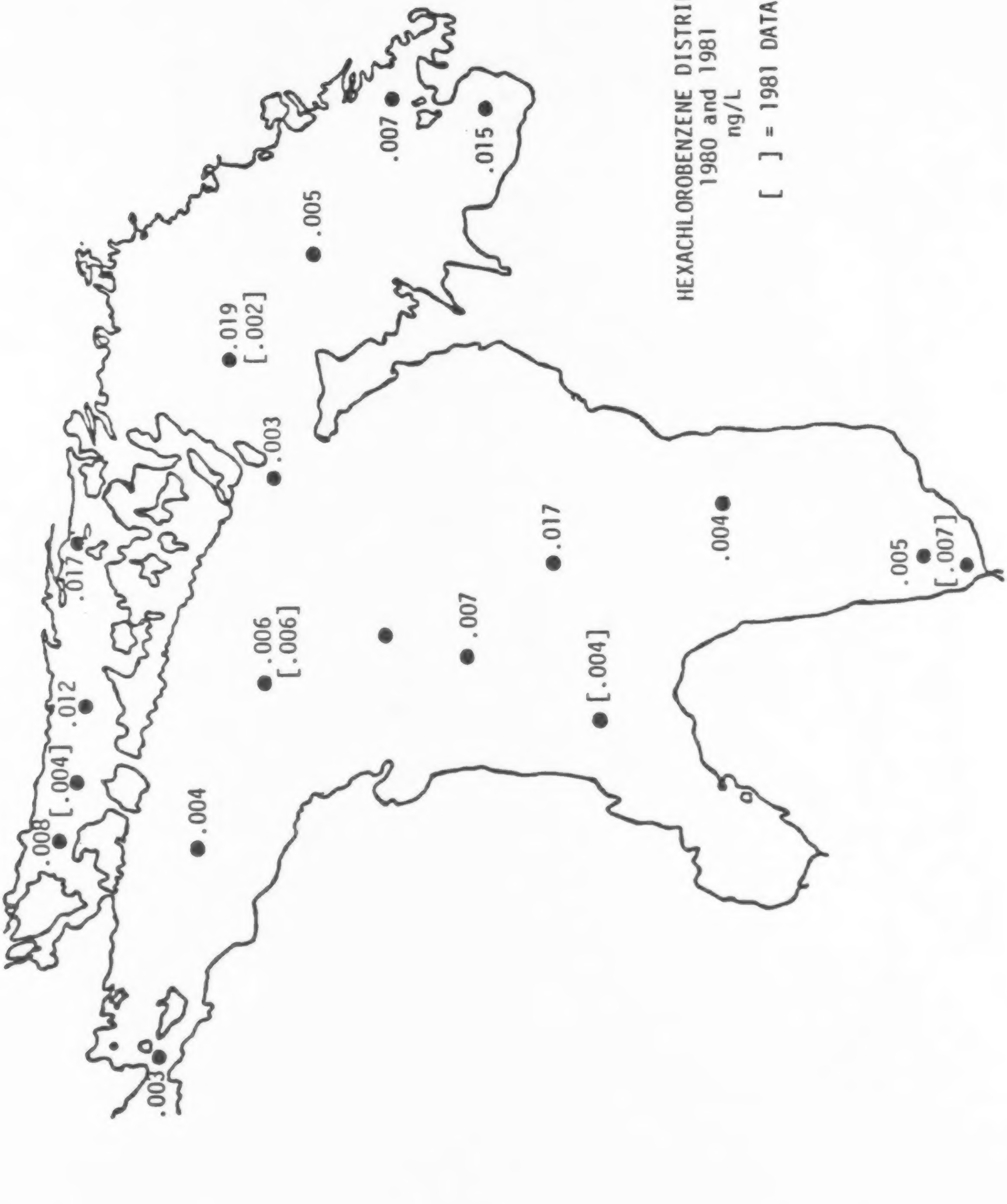
PENTACHLOROBENZENE DISTRIBUTION
1980 and 1981
ng/L
[ ] = 1981 DATA

Figure 4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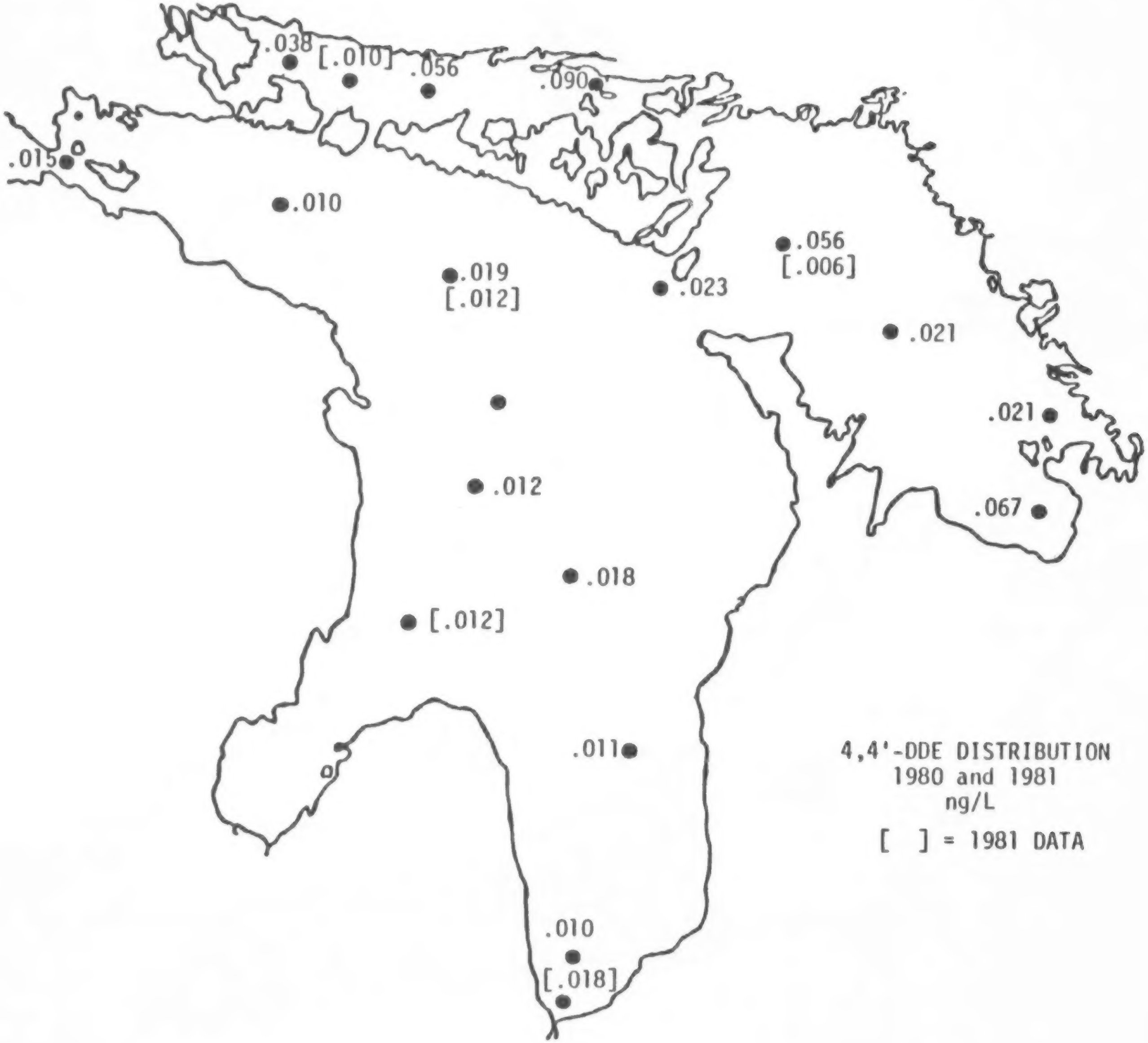
HEXACHLOROBENZENE DISTRIBUTION
1980 and 1981
ng/L

[ ] = 1981 DATA

Figure 5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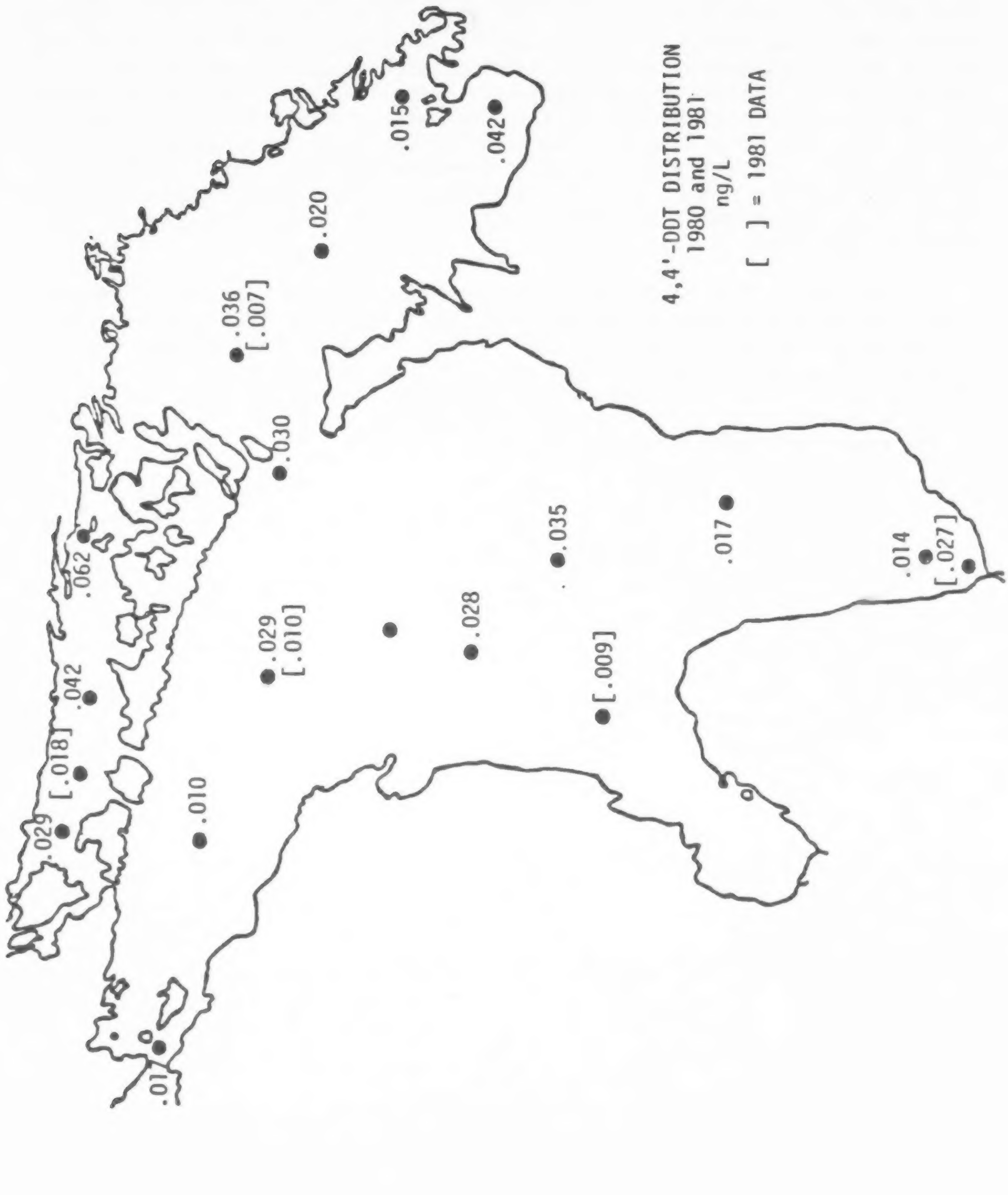
4,4'-DDE DISTRIBUTION
1980 and 1981
ng/L

[ ] = 1981 DATA

Figure 6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4,4'-DDT DISTRIBUTION
1980 and 1981
ng/L
[ ] = 1981 DATA